JOURNAL OF AGRICULTURAL RESEARCH

VOL. 52 WASHINGTON, D. C., JUNE 1, 1936 No. 11

LENGTH OF THE DORMANT PERIOD IN CEREAL SEEDS [1]

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INTRODUCTION

Cereals from a great variety of sources have been used in hybridization experiments to improve the yield and quality of the grain. Little or no account appears to have been taken, however, of the factor of dormancy in the varieties used for crossing. Doubtless parent plants grown under different climatic conditions often differ in many other factors than those desired to combine in breeding, and these characters are not easily determined by the yield and quality of the grain or the anatomical structure of the plant. This paper deals with one such character—the heritable differences in the length of the rest period.

In this study all types of summer and winter cereals, grown as nearly as possible under the same conditions, were used. Because of the large number of varieties employed it was necessary to use seed grown in field plots. The use of field-grown material has some practical advantages, for the effects on dormancy produced by conditions in the field may differ from those produced under controlled conditions in the greenhouse.

METHODS

Samples for testing were collected from cereals growing on field plots at University Farm, St. Paul, Minn. The plants were grown under fairly uniform conditions.

Since it was known that the stage of maturity of the seed affects the length of its rest period, samples were collected at three stages of maturity—soft dough, hard dough, and ripe. It was not possible to determine these stages accurately. Collections of all varieties of a certain stage of maturity generally were made on the same date, which is recorded together with the dates of the germination trials. Spring wheats were collected later than winter wheats. Collections were made of early and of late oat varieties.

It was thought that temperature might affect the length of the rest period, and each collection was accordingly stored at electrically controlled constant temperatures, as follows: 0°, 10°, and 20° C. during the experiment of 1929; 0°, 7°, and 14° in 1930; and 0°, 10°, 20°, 30°, and 35° for a few varieties in 1931. All the samples were stored in paper bags and kept in darkness except for such periods as

[1] Received for publication Mar. 26, 1935; issued July 1936. Published as Journal Series Paper No. 1345 of the Minnesota Agricultural Experiment Station.

[2] The authors are indebted to Clarence Jonk, Ira Takle, and the staff of the Minnesota State Seed Laboratory for assistance in germination tests, and to the Division of Agronomy and Plant Genetics of the Minnesota Station for the samples of cereals used in the tests.

they were required for sampling. The humidity of the storage rooms was not determined or controlled. The storage temperature was electrically controlled to within ±1°. When doors were opened, the temperature sometimes rose as much as 2° to 3° for a few minutes.

The probable response of the cereals to conditions of high humidity in the shock or stack for short periods after rains is indicated by the rapidity of sprouting in the germination tests. However, these tests were all made at one temperature, 20° C., and it was not therefore possible from these data to combine the effects of high humidity with different temperatures in germination. Higher or lower temperatures combined with high humidity in wet shocks or stacks may be expected to modify the germination rate.

Germination tests were made in electrically controlled germinators which varied less than 1° from 20° C. The tests were made under the standard conditions recommended by the Association of Official Seed Analysts of North America,[3] and the equipment of the Minnesota State Seed Laboratory was used. Germination counts were made on the third, fifth, and seventh day of the test to indicate the speed of germination. Tests were made at intervals to determine the length of the dormant period for each variety. The dates of collection and determination of percentage germination are recorded, since the date of ripening differs from year to year.

PRESENTATION OF DATA

That there are great varietal differences in the length of the rest period in cereals not determined entirely by ecological or physiological conditions is shown by the data in tables 1 to 14. The lower the temperature of storage, the longer is the rest period. Cutting the plants while still unripe generally increases the length of the afterripening period.

Among the barleys (tables 1–3) there was a considerable difference in the rate of germination. The variety with the longest rest period was Trebi 448. When the plants were cut ripe only 8 percent of the seed germinated (table 2) after 73 days' storage at 0° C., 18 percent after 73 days' storage at 7°, 10 percent after 27 days at 14°, and 100 percent after 52 days at 14°. Colcess 461 also had a rather long dormant period. Manchuria, Velvet, and Peatland had very short rest periods when stored at 14° even if cut in the soft-dough stage.

Nearly all of the rye varieties (tables 4–6) showed a high germination percentage when cut ripe and stored at 14°. Green Select 102 and Prolific had the longest afterripening periods. Montagney seems to be characterized by a much shorter afterripening period than other varieties. This is evident in early cuttings. When plants of this variety were cut in the soft-dough stage and the seed was stored for 30 days 78 percent of that stored at 0° germinated and 88 percent of that stored at 14°.

Oats (tables 7–10) cut in the ripe stage generally had only a short rest period. Gopher oats cut ripe finished their afterripening and germinated completely within 26 days. If a shorter time of storage should be taken, it would be difficult to separate the effects of the

[3] UNITED STATES DEPARTMENT OF AGRICULTURE. RULES FOR SEED TESTING. Dept. Cir. 406, 13, pp. 1927.

storage temperature from the effects of the temperature during germination. When oats are cut green, the rest period is increased, and the seed shows less tendency to sprout immediately. Low temperatures further increase the length of the rest period.

Winter wheats (tables 11–13) showed great varietal differences in the length of their rest periods. Allowing the wheat to become fully ripe decreased the time required for afterripening. Winter wheats generally had a shorter rest period than spring wheats. Two separate crosses, Minard × Minhardi no. 2313 and no. 2314, to form the same hybrid between two winter wheat varieties, showed great similarity in their rest periods. Minturki wheat has a shorter rest period than Minard, which has a shorter rest period than Minhardi. The cross Minhardi × Minturki has a shorter rest period than Minard × Minhardi.

Minturki seed at 14° germinated with great energy after 23 days' storage, whether cut in the soft-dough, hard-dough, or ripe stages, but lowering the storage temperature to 0° decreased the rapidity of germination. Lowering the storage temperature to 7° decreased the rapidity of germination of that cut in the ripe stage.

When Marquis wheat has completed its rest period, the rapidity or energy of germination increases; that is, a high percentage germinates after the seed has been held under conditions favorable for germination for 3 days.

Among the spring wheat varieties (tables 11, 12, and 14), some have a notably long rest period, failing to germinate until so late in autumn that if planted out of doors in Minnesota temperature conditions would prevent their germination and enforce a dormancy until spring. Mindum 470, Marquillo 2202, Kubanka 2310, and Double Cross 2303, 2304, and 2305 have notably long rest periods. After storage for 2 months at freezing temperatures, they give practically no germination. At 7° storage the rest period is more than 2 months, and at 14° it is about a month. Double Cross 2315 and 2316 showed a slightly higher germination percentage on the third test than Double Cross 2303.

When cut ripe and stored at 14°, the rest period is about 23 days for Kubanka 2310, Reward 2204, Supreme 2309, Ceres 2223, and Reliance 2308.

From the results of 1929 and 1930 it seemed desirable to test at shorter intervals the germination of some varieties that had shown a very short rest period and to extend the range of storage temperatures to 30° and 35°. This was done in 1931 with a few varieties of each cereal. The results of the first 2 years indicated that at low temperatures the importance of the length of the rest period was emphasized. In the experiments of 1929 and 1930 the temperatures used were such as occur after harvest time in northern Minnesota in certain years. In other years, however, the period following harvest, is very hot, and it was thought that temperatures of 30° and 35° probably would not be above those that might obtain at times in cereals in the shock.

In winter wheat (table 13) collected in the hard-dough stage, the germination percentage was higher after 2 days storage at 0°, 10°, and 20° C. than after 9 days (second test) or 20 days (third test) storage at these temperatures. Evidently the seed had not gone into its deepest rest when collected in the hard-dough stage, and required about

9 days to reach maximum dormancy. When stored at 30° or 35°, this was not the case, and the percentage germination increased with time of storage except in the case of Minhardi, which did not consistently increase. When the seed was collected ripe, this decrease in germination was not found. Storage of Minturki wheat, in the hard-dough stage, at 30° for 9 days was as effective in breaking the rest period as storage for more than 40 days at 0° or 10°. At 20° the time required to reach 90 percent germination (7-day count) was 30 days. For Minhardi × Minard and Minhardi × Minturki the reactions to storage temperatures were somewhat similar to those of Minturki. Storage for only 2 days at all of the various temperatures gave nearly the same percentage germination of winter wheat collected in the hard-dough stage as can be expected for such a short period of storage; in fact, the germination period at 20° was longer than the storage period. Tests at such a short storage interval as 2 days were made only on the hard-dough stages of winter wheat and rye. The other samples were put directly under germinating conditions at 20° on the day of collection. The values of this test were taken as the original germination percentage and tests were not again made until the lapse of about 1 week.

In the data on spring wheat (table 14) collected in the hard-dough stage, there is also some indication of a decrease in germination percentage on the second test. This increase in depth of the resting condition is indicated also in collections in the hard-dough stage in rye (table 6), oats (tables 9 and 10), and barley (table 3), but is generally not shown in the collections of ripened grain.

The effect of the higher temperatures in speeding up the afterripening processes is noticeable especially in collections in the hard-dough and ripe stages of winter and of spring wheats, oats, and barley. In certain cases the higher storage temperature seem to have decreased germination on the second test of rye collected in the hard-dough stage. The greater length of the rest period of Prolific 89 rye is marked.

In oats a rest period of any considerable length was found only in the late varieties. The rest period was longer in North Dakota 20014 than in any other variety. Cutting early or in the hard-dough stage is indicated as a possible means of increasing the length of the rest period, but this might be effective only if the temperature is low, for the rest period is quickly passed at high temperatures.

SUMMARY

The length of the rest period of common varieties of wheat, oats, barley, and rye was determined by germination tests at three stages of ripeness: Soft dough, hard dough, and ripe. The rest period was found to be longest in immature seeds. Lowering the temperature at which the seed was stored generally increased the length of the rest period. The length of the rest period varied greatly with the variety. Generally speaking, winter wheats had a shorter rest period than spring wheats.

TABLE 1.—*Percentages of germination of barley varieties harvested at different stages of maturity and stored at different temperatures, 1929*

[100 seeds taken for each test]

Storage temperature and variety	Germination at soft-dough stage, collected July 17, after storage for indicated number of days						Germination at ripe stage, collected July 26, after storage for indicated number of days					
	First test [1]		Second test [2]		Third test [3]		First test [1]		Second test [2]		Third test [3]	
	5	7	5	7	5	7	5	7	5	7	5	7
0° C.:												
Manchuria × South African 457	1	15	0	8	32	40	0	2	2	10	19	21
Mechanical mixture	1	8	2	3	22	24	7	10	2	8	77	81
Manchuria 184	10	20	18	24	28	28	0	1	3	6	85	85
Composite crosses 41	2	5	8	25	24	33	4	8	0	2	71	77
Colsess 461	0	2	0	3	12	17	0	1	4	6	7	10
Svanhals × Lyon 474							12	33	5	20	53	67
Small awn × Manchuria 412							4	5	5	13	27	34
Heinrich's 465	3	36	38	63	91	97	0	1	62	65		
Glabron 445	0	2	0	3	3	6	1	3	2	8	18	28
Svansota 440	3	10	0	5	27	33	4	4	1	7		
Velvet 447	2	16	4	18	96	97	5	12	8	12	88	88
Trebi 448	3	19	0	12	45	56	1	2	6	23	54	66
Peatland 452	4	31	9	27	80	97	7	9	83	86	100	100
Minsturdi 439	4	16	28	51	87	89	3	5	16	22	94	95
10° C.:												
Manchuria × South African 457	1	2	3	7			1	8	7	15		
Mechanical mixture	0	0	1	2			2	6	25	31	100	100
Manchuria 184	3	5	13	14			12	14	21	24	98	98
Composite crosses 41	1	3	10	11			2	12	24	38		
Colsess 461	1	1	2	3			1	3	27	30	6	22
Svanhals × Lyon 474							1	7	3	11	89	89
Small awn × Manchuria 412							2	5	8	15		
Heinrich's 465	0	0	26	29			0	0	19	31	93	93
Glabron 445	0	0	1	2	37	41	0	1	8	10	70	72
Svansota 440	0	0	10	11	24	25	0	1	35	49	99	99
Velvet 447	0	0	11	13			4	10	49	64	98	98
Trebi 448	0	1	3	13	30	41	1	2	2	8	33	64
Peatland 452	0	2	29	33			4	5	93	95		
Minsturdi 439	1	8	28	46			0	13	61	69		
20° C.:												
Manchuria × South African 457	9	16	91	94			3	13	83	84		
Mechanical mixture	1	1	59	63	100	100	1	3	86	87		
Manchuria 184	4	6	75	75			4	6	75	75		
Composite crosses 41	15	26	38	41	94	94	7	13	66	73		
Colsess 461	6	10	31	43	58	62	3	3	1	8	58	70
Svanhals × Lyon 474							4	9	78	82		
Small awn × Manchuria 412							4	6	79	82		
Heinrich's 465	6	7	100	100			2	6	98	99		
Glabron 445	4	6	58	62			1	2	59	67	95	95
Svansota 440	2	3	100				0	4	99	100		
Velvet 447	2	2	100	100			2	11	98	98		
Trebi 448	9	14	27	35	58	73	1	3	98	99		
Peatland 452	43	46	100	100			70	74	100	100		
Minsturdi 439	4	23	16	37			2	17	100	100		

[1] Begun Aug. 8, ended Aug. 15.
[2] Begun Sept. 5, ended Sept. 12.
[3] Begun Sept. 25, and Oct. 2.

TABLE 2.—*Percentages of germination of barley varieties harvested at different stages of maturity and stored under different temperatures, 1930*

[50 seeds taken for each test]

Storage temperature and variety	Germination at soft-dough stage, collected July 9 after storage for indicated number of days									Germination at hard-dough stage, collected July 14, after storage for indicated number of days									Germination at ripe stage, collected July 18, after storage for indicated number of days								
	First test [1]			Second test [2]			Third test [3]			First test [4]			Second test [5]			Third test [6]			First test [7]			Second test [8]			Third test [9]		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																											
Manchuria × South African 457	0	0	4	0	0	6	0	0	0	0	0	0	0	0	0	0	12	12	10	16	38	20	34	44	68	92	92
Mechanical mixture	0	0	12	0	0	6	0	0	2	0	2	4	2	2	4	8	24	26									
Manchuria 184	0	0	6	0	2	2	0	4	6	0	2	6	18	28	30	30	34	40	34	42	50	54	56	64	96	98	98
Composite crosses	0	2	8	0	0	4	0	0	4	4	6	10	0	10	14	12	36	38									
Colsess 461	0	0	6	0	0	0	0	0	0	0	2	2	0	6	10	4	8	14	0	4	6	0	0	2	2	12	12
Svanhals × Lion 474	0	0	6	0	0	4	0	0	0	6	24	28	16	32	38	22	50	50	0	4	14	0	0	4	8	30	36
Svanhals × Lion 475	0	0	2	0	0	0	0	4	6	0	0	6	0	6	10	8	10	14	0	8	34	8	16	32	2	42	60
Small awn × Manchuria 412	0	0	8	0	2	10	0	4	6	0	0	0	0	0	2	8	20	22	4	8	16	24	46	58	54	74	78
Heinrichs 465	0	0	2	0	0	8	0	0	0	4	6	12	24	26	66	86	86	0	8	26	14	28	36	38	82	86
Glabron 445	0	0	4	0	0	12	2	2	2	0	2	2	0	0	2	0	10	12	10	24	52	32	56	68	80	98	98
Svansota 440	0	2	14	0	0	20	2	2	2	4	20	22	30	50	58	56	72	72	0	2	16	2	4	18	28	72	78
Velvet 447	0	0	6	0	0	0	2	2	2	4	20	22	56	62	70	84	92	92	46	78	92	98	98	98	100		
Trebi 448	0	2	18	0	0	26	2	2	14	0	2	4	0	6	18	0	10	18	0	2	2	0	0	4	0	4	8
Peatland 452	0	0	0	0	2	4	0	0	0	2	8	12	72	78	82	94	94	94	94	94	96	98	98	98	100		
Minsturdi 439	2	4	16	0	0	18	0	0	12	0	6	8	0	22	34	14	54	70	4	24	68	24	58	72	76	100	
7° C.:	0	0	2	0	0	0	20	30	42																		
Manchuria × South African 457	0	0	0	0	0	4	2	4	6	0	2	2	4	10	12	24	44	44	10	24	52	66	78	86	94	96	96
Mechanical mixture	0	2	4	0	2	2	2	2	6	0	2	4	4	8	20	54	54	54									
Manchuria 184	0	0	2	2	4	6	24	26	26	12	20	20	46	54	60	84	92	94	46	60	72	92	96	96	100		
Composite crosses	0	0	2	0	0	0	6	12	14	0	2	6	10	14	22	12	26	28									
Colsess 461	0	0	2	0	0	2	2	2	2	0	2	2	2	4	4	0	2	4	0	6	8	0	2	8	4	18	22
Svanhals × Lion 474	0	0	0	0	0	0	0	0	4	0	12	14	20	32	40	46	96	96	0	4	20	2	32	50	48	86	86
Svanhals × Lion 475	0	0	2	0	0	0	0	0	2	2	8	10	6	14	20	4	12	16	8	18	52	14	34	52	22	64	68
Small awn × Manchuria 412	0	0	2	0	0	0	0	0	2	0	0	2	2	2	6	14	44	46	56	64	78	76	84	88	98	98	98
Henricks 465	0	0	0	0	0	2	0	0	0	0	4	6	52	76	82	76	100		2	26	70	40	82	96	98	100	
Glabron	0	0	0	0	0	2	0	0	0	0	6	8	12	14	22	50	66	70	10	20	38	64	76	82	94	98	98
Svansota 440	0	2	12	0	2	14	4	6	54	0	4	4	22	26	28	86	94	98	14	72	92	84	96	98	100		
Velvet 447	0	2	4	0	0	4	4	4	4	2	4	4	22	26	28	86	94	98	14	72	92	84	96	98	100		
Trebi 448	0	0	0	0	0	0	74	76	76	0	32	40	90	94	96	100			78	92	92	100			100		
Peatland 452	0	0	0	0	0	0	0	0	0	0	0	0	2	2	6	2	28	30	0	0	2	0	0	4	0	12	18
Minsturdi 439	0	0	2	0	4	20	64	70	70	12	24	36	98	98	98	100			100			96	96	96	100		
										0	2	14	8	42	66	68	92	94	20	66	82	82	94	96	98	100	
14° C.:																											

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TABLE 3.—*Percentages of germination of barley varieties harvested at different stages of maturity and stored at different temperatures, 1931*

[100 seeds collected for each test]

HARD-DOUGH STAGE, COLLECTED JULY 11[1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0°C.:																		
Peatland 452	----	----	----	1	1	3	4	13	42	5	16	48	40	44	51	66	78	81
Trebi 448	----	----	----	0	0	3	0	0	31	1	2	19	0	1	13	0	3	6
Manchuria 184	----	----	----	1	2	4	3	3	5	5	6	9	7	7	8	6	7	8
Glabron 445	----	----	----	0	0	1	4	6	12	0	0	0	0	0	2	0	3	5
10°C.:																		
Peatland 452	----	----	----	2	5	8	22	34	45	45	59	67	63	67	71	69	74	77
Trebi 448	----	----	----	2	3	4	2	11	23	5	15	40	7	9	22	4	12	23
Manchuria 184	----	----	----	5	12	17	14	24	31	27	31	38	31	33	37	26	32	34
Glabron 445	----	----	----	2	4	7	1	5	10	4	6	20	6	9	15	1	7	9
20°C.:																		
Peatland 452	0	0	1	12	18	23	46	50	55	78	86	88	95	96	97	100	----	----
Trebi 448	1	1	2	2	2	2	2	9	15	1	6	7	9	13	17	9	15	17
Manchuria 184	1	4	5	10	14	14	23	24	26	27	27	29	31	31	33	36	41	48
Glabron 445	3	4	10	0	0	0	0	1	1	0	2	2	2	2	4	5	5	9
30°C.:																		
Peatland 452	----	----	----	40	97	97	100	----	----	99	99	99	98	98	98	100	----	----
Trebi 448	----	----	----	0	0	2	0	0	6	0	2	6	0	6	12	2	88	95
Manchuria 184	----	----	----	11	23	31	64	88	96	98	100	----	98	98	98	99	100	----
Glabron 445	----	----	----	13	25	41	79	96	97	91	97	97	99	99	99	99	99	99
35°C.:																		
Peatland 452	----	----	----	82	99	100	100	----	----	100	----	----	98	100	----	100	----	----
Trebi 448	----	----	----	2	7	11	7	7	9	9	15	24	42	63	80	26	96	98
Manchuria 184	----	----	----	21	33	48	95	100	----	97	99	99	99	99	99	100	----	----
Glabron 445	----	----	----	1	4	17	76	93	96	85	99	99	99	99	99	99	99	99

RIPE STAGE, COLLECTED JULY 20[2]

0°C.:																		
Peatland 452	----	----	----	90	93	93	97	98	98	93	93	94	99	99	99	100	----	----
Trebi 448	----	----	----	0	1	1	0	0	0	0	0	0	0	0	3	0	1	2
Manchuria 184	----	----	----	22	32	50	21	24	34	29	42	54	36	44	57	27	54	68
Glabron 445	----	----	----	5	19	39	0	11	31	1	14	36	3	10	28	12	33	48
10°C.:																		
Peatland 452	----	----	----	92	94	94	92	95	96	94	94	95	96	96	96	100	----	----
Trebi 448	----	----	----	1	2	4	0	0	1	0	0	0	1	1	2	0	1	2
Manchuria 184	----	----	----	16	35	53	13	20	30	27	35	50	38	46	57	67	82	87
Glabron 445	----	----	----	6	16	34	13	19	25	14	35	54	22	40	55	33	55	66
20°C.:																		
Peatland 452	86	96	98	100	----	----	100	----	----	100	----	----	100	----	----	100	----	----
Trebi 448	0	0	2	0	0	1	0	1	2	0	0	4	0	1	3	1	6	11
Manchuria 184	13	31	43	19	41	57	14	29	48	83	92	95	98	98	98	100	----	----
Glabron 445	3	10	29	3	32	47	13	34	51	55	77	84	83	89	93	98	98	98
30°C.:																		
Peatland 452	----	----	----	99	100	----	98	98	98	99	99	99	100	----	----	100	----	----
Trebi 448	----	----	----	0	0	1	0	3	8	9	77	88	36	93	100	66	100	----
Manchuria 184	----	----	----	87	100	----	100	----	----	99	100	----	100	----	----	100	----	----
Glabron 445	----	----	----	82	96	98	97	98	99	99	99	99	98	98	98	97	97	97
35°C.:																		
Peatland 452	----	----	----	99	99	99	100	----	----	100	----	----	100	----	----	100	----	----
Trebi 448	----	----	----	0	3	7	0	8	18	8	79	97	33	99	99	88	98	98
Manchuria 184	----	----	----	96	98	99	100	----	----	100	----	----	99	100	----	100	----	----
Glabron 445	----	----	----	86	94	95	91	94	95	99	100	----	97	98	99	99	100	----

[1] The first test was made July 11, second test July 18, third test July 25, fourth test Aug. 1, fifth test Aug. 8, sixth test Aug. 15.

[2] The first test was made July 20, second test July 28, third test Aug. 3, fourth test Aug. 10, fifth test Aug. 17, sixth test Aug. 24.

TABLE 4.—*Percentages of germination of rye varieties harvested at different stages of maturity and stored at different temperatures, 1929*

[100 seeds taken for each test]

Storage temperature and variety	Germination at soft-dough stage, collected July 2, after storage for indicated number of days					Germination at hard-dough stage, collected July 6, after storage for indicated number of days					Germination at ripe stage, collected July 10, after storage for indicated number of days				
	First test [1]			Second test [2]		First test [1]			Second test [2]		First test [1]			Second test [2]	
	3	5	7	3	7	3	5	7	5	7	3	5	7	3	7
0° C.:															
Green select 102	47	57	66	52	66	53	71	83	79	87	64	70	75	94	96
Rosen 82	76	81	85	12	27	86	90	92	94	98	76	81	85	94	100
Prolific 89	72	83	86	12	26	13	20	29	30	39					
Synthetic 92	40	43	51	70	78	89	90	94	93	98	72	79	84	95	99
Emerald 92	41	53	63	48	62	85	90	91	90	96	84	91	95	100	
Colorless 104	47	55	64	48	61	62	72	76	89	93	76	83	89	79	90
Swedish 2	65	79	86	74	83	67	86	89	94	99	78	92	93	98	99
Dakold 93	76	78	82	83	89	84	94		95	98	77	85	87	86	99
Green select 103	20	26	36	15	25	87	94	96	66	87	45	60	67	90	92
Synthetic 90	28	34	42	32	47	87	92	93	97	99	67	82	86	95	98
Synthetic 91	75	76	78	69	76	87	91	92	94	94	98			99	99
10° C.:															
Green select 102	59	70	73	77	83	84	85	87	98	98	93	97	99	98	98
Rosen 82	11	29	34	47	79	92	93	95	92	94	88	95	96	100	
Prolific 89	3	8	13	20	27	3		4	8	15					
Synthetic 92	27	33	42	49	66	96	99		100		95			100	
Emerald 92	39	49	62	68	85	99			100		97	98		99	99
Colorless 104	43	56	62	77	89	91	95	96	95	97	85	95	96	96	97
Swedish 2	55	67	73	87	92	100			100		100			99	99
Dakold 93	75	81	86	96	98	95	100		97	98	98	100		95	97
Green select 103	15	30	40	53	75	91	93		95	95	97	99		100	
Synthetic 90	27	36	47	69	83	99			98	99	96	97		100	
Synthetic 91	36	48	62	80	92	99			100		99		100	100	
20° C.:															
Green select 102				90	92	94	96		92	92	86	92	93	97	97
Rosen 82	66	87	91	97	97	78	92	94	100		97	98		97	97
Prolific 89	87	92	94	99	99	54	61	67	86	91					
Synthetic 92	78	94	95	97	97	87	93	96	99	99	90	97		99	100
Emerald 92	87	95	96	95	98	96	98	99	100		97	99		99	99
Colorless 104	80	94		92	94	89	95		99	99	86	92	93	98	98
Swedish 2	91	97	98	99	99	95	97	98	100		97	99		97	98
Dakold 93	93	98		98	99	96	99		99	99	89	94	96	100	
Green select 103	76	88	93	93	96	97	98	99	98	98	93	97	97	100	
Synthetic 90	60	77	83	99	99	85	91	92			89	98	98	99	97
Synthetic 91	76	83	84	93	93	96			100		98	98	98	100	

[1] Begun Aug. 14, ended Aug. 21.

[2] Begun Sept. 10, ended Sept. 17.

TABLE 5.—*Percentages of germination of rye varieties harvested at different stages of maturity and stored at different temperatures, 1930*

[50 seeds taken for each test]

Storage temperature and variety	Germination at soft-dough stage, collected June 28, after storage for indicated number of days									Germination at hard-dough stage, collected July 2, after storage for indicated number of days									Germination at ripe stage, collected July 11, after storage for indicated number of days								
	First test [1]			Second test [2]			Third test [3]			First test [4]			Second test [5]			Third test [6]			First test [7]			Second test [8]			Third test [9]		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																											
Green Select 102	4	10	16	0	2	14	0	6	16	8	14	14	12	22	22	6	12	32	54	66	80	88	96	96	100	----	----
Rosen 82	6	28	36	0	6	14	0	6	18	0	4	12	4	6	10	2	16	28	84	88	94	96	98	98	100	----	----
Prolific 89	2	14	20	0	4	18	0	4	10	0	12	12	0	4	8	0	2	16	64	66	68	92	96	96	98	98	98
Synthetic 92	8	22	42	0	2	10	2	2	28	18	22	34	38	48	52	36	38	44	70	78	82	94	94	96	94	96	96
Emerald 92	0	8	20	0	8	30	0	4	32	16	22	34	26	38	44	30	34	54	80	84	90	90	90	94	100	----	----
Colorless 104	16	34	40	0	8	16	0	8	30	2	2	12	12	18	22	4	10	30	66	68	76	84	86	92	94	94	100
Swedish 2	6	14	26	2	14	28	2	10	24	20	28	42	40	44	52	36	40	54	94	98	98	98	98	98	98	98	98
Dakold 93	16	34	46	6	20	36	8	16	44	70	70	76	72	86	88	82	94	96	90	92	94	100	----	----	98	98	98
Montagney	50	70	78	12	60	82	10	58	80	74	84	92	78	92	98	76	88	96	100	----	----	100	----	----	100	----	----
Green Select 103	10	22	34	0	2	20	0	12	28	14	18	26	22	30	36	12	22	42	80	86	86	98	98	98	100	----	----
Synthetic 90	4	14	16	0	0	2	0	0	10	44	44	50	42	48	56	28	36	50	72	78	80	96	98	98	98	98	100
Synthetic 91	12	32	40	0	9	16	2	14	36	34	36	40	52	20	22	48	56	68	76	76	84	96	96	98	100	----	----
7° C.:																											
Green Select 102	2	8	16	0	2	14	0	0	2	2	4	18	16	26	28	48	60	70	44	50	72	94	94	94	100	----	----
Rosen 82	10	12	16	2	2	4	2	2	6	2	2	6	28	42	48	64	76	82	76	78	90	94	94	98	100	----	----
Prolific 89	0	2	4	0	4	6	0	8	16	0	0	0	0	0	10	44	54	60	68	70	80	90	90	90	100	----	----
Synthetic 92	0	4	4	0	2	4	0	4	20	18	22	26	70	78	78	82	92	92	80	82	92	100	----	----	100	----	----
Emerald 92	2	4	10	6	8	18	2	8	26	8	10	30	60	68	70	68	80	86	80	84	92	96	96	96	100	----	----
Colorless 104	0	4	6	0	2	4	4	6	24	2	2	10	14	24	32	74	78	82	62	64	82	90	92	98	94	100	----
Swedish 2	0	4	16	8	24	40	8	30	64	6	12	30	46	54	56	90	94	96	86	88	92	100	----	----	100	----	----
Dakold 93	12	22	26	10	16	24	24	34	50	32	44	58	78	90	90	100	----	----	86	86	88	100	----	----	98	98	98
Montagney	34	58	76	30	56	74	56	68	78	68	82	92	92	100	----	92	94	94	98	98	98	98	98	98	100	----	----
Green Select 103	2	2	6	0	0	10	4	14	34	12	14	22	30	58	58	76	94	94	88	92	96	98	98	98	100	----	----
Synthetic 90	6	6	6	16	16	18	18	24	28	18	20	36	54	64	64	84	90	92	84	88	94	98	98	98	100	----	----
Synthetic 91	6	10	16	0	8	12	8	20	46	24	38	46	88	92	92	100	----	----	88	90	98	96	98	98	98	100	----
14° C.:																											
Green Select 102	2	2	6	10	20	32	68	82	84	0	8	14	98	98	98	98	100	----	38	44	56	96	96	96	96	98	98
Rosen 82	12	16	24	88	92	96	98	98	98	4	12	30	94	94	94	96	96	96	68	76	82	98	98	98	96	96	96
Prolific 89	0	10	22	38	56	62	52	62	62	2	6	14	98	98	98	100	----	----	32	50	64	100	----	----	100	----	----
Synthetic 92	54	56	62	62	68	76	88	98	100	32	42	58	96	100	----	96	98	100	70	74	82	100	----	----	98	98	98
Emerald 92	4	8	8	46	48	50	78	92	94	16	38	48	92	92	94	96	98	98	80	88	92	100	----	----	100	----	----
Colorless 104	14	24	32	80	82	86	84	94	94	12	40	50	100	----	----	100	----	----	78	82	86	100	----	----	100	----	----

Swedish 2	12	30	40	88	94	94	86	90	92	28	42	58	100	----	----	100	86	88	96	100	----	----	100	----	----	----	----	----	----	----
Bredol 93	26	30	50	98	96	96	96	100	----	34	56	74	96	100	----	----	98	100*	82	88	90	100	----	----	100	----	----	----	----	----
Montagney	84	86	88	78	80	88	98	98	98	96	98	98	100	----	----	100	----	----	100	----	----	----	----	----	----	----	----	----	98	98
Green Select 103	4	6	10	84	90	92	100	----	----	14	26	34	98	100	----	100	----	----	78	84	86	100	----	----	----	----	----	----	100	----
Synthetic 90	0	0	0	38	46	48	90	96	96	14	26	32	98	98	98	90	92	96	70	74	92	100	----	----	98	98	98	98	98	98
Synthetic 91	14	22	42	54	58	64	92	96	96	22	34	50	100	----	----	100	----	----	56	72	78	94	94	96	98	98	98	98	98	98

1 Begun July 28, ended Aug. 4.
2 Begun Aug. 21, ended Aug. 28.
3 Begun Sept. 12, ended Sept. 29.
4 Begun Aug. 4, ended Aug. 11.
5 Begun Sept. 2, ended Sept. 9.
6 Begun Sept. 22, ended Sept. 29.
7 Begun Aug. 13, ended Aug. 20.
8 Begun Sept. 8, ended Sept. 15.
9 Begun Sept. 26, ended Oct. 3.

TABLE 6.—*Germination percentages of rye varieties harvested at different stages of maturity and stored at different temperatures, 1931*

[100 seeds collected for each test]

HARD-DOUGH STAGE, COLLECTED JULY 6[1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Green Select 102	50	61	63	73	90	94	79	90	93	79	91	96	80	90	95	87	97	98
Rosen 82	21	30	39	78	88	91	78	86	88	82	91	96	67	78	94	85	95	98
Prolific 89 [2]	----	----	----	1	5	22	2	14	23	5	14	21	9	17	33	9	17	35
Emerald 92	73	83	86	92	96	96	80	86	91	86	95	96	90	98	98	95	97	97
10° C.:																		
Green Select 102	54	75	77	43	68	79	84	93	96	92	97	98	81	95	97	95	97	98
Rosen 82	26	45	56	70	85	91	65	84	89	88	93	95	82	92	95	96	100	----
Prolific 89 [2]	----	----	----	1	5	9	4	10	25	0	5	22	21	26	39	18	31	45
Emerald 92	76	83	88	83	88	88	92	95	96	96	98	99	94	98	99	100	----	----
20° C.:																		
Green Select 102	47	69	76	30	60	63	43	70	74	87	94	95	88	96	99	98	100	----
Rosen 82	20	34	49	19	40	46	34	73	81	81	90	95	79	92	96	89	96	97
Prolific 89 [2]	2	4	25	2	19	26	6	28	45	14	23	33	60	72	79	84	92	93
Emerald 92	75	86	87	75	87	89	82	92	96	95	98	99	100	----	----	100	----	----
30° C.:																		
Green Select 102	59	76	86	34	68	71	29	83	87	88	99	100	90	99	100	100	----	----
Rosen 82	25	45	53	49	78	86	42	86	91	96	99	99	93	99	99	100	----	----
Prolific 89 [2]	----	----	----	2	8	28	13	39	73	61	72	84	98	100	----	100	----	----
Emerald 92	77	86	89	45	60	73	74	93	94	100	----	----	100	----	----	100	----	----
35° C.:																		
Green Select 102	52	80	87	14	50	59	66	88	92	92	98	98	99	100	----	100	----	----
Rosen 82	22	45	54	28	40	49	64	82	84	90	92	94	97	98	98	100	----	----
Prolific 89 [2]	----	----	----	5	21	42	41	71	86	81	94	96	97	98	98	100	----	----
Emerald 92	80	89	90	62	78	87	88	94	96	99	100	----	98	98	98	100	----	----

RIPE STAGE, COLLECTED JULY 20[3]

0° C.:																		
Green Select 102	----	----	----	65	82	93	76	94	97	100	----	----	98	99	99	100	----	----
Rosen 82	----	----	----	59	80	86	68	80	94	97	98	98	96	97	97	98	98	98
Prolific 89	----	----	----	28	56	69	50	61	78	76	87	90	88	96	98	88	94	96
Emerald 92	----	----	----	93	99	99	97	98	99	98	99	9	99	99	99	96	97	98
10° C.:																		
Green Select 102	----	----	----	70	88	91	80	93	95	100	----	----	100	----	----	99	99	99
Rosen 82	----	----	----	68	86	94	74	87	94	100	----	----	99	99	99	100	----	----
Prolific 89	----	----	----	23	65	74	76	88	91	94	97	98	97	100	----	99	100	----
Emerald 92	----	----	----	89	96	99	99	99	99	98	98	98	99	99	99	100	----	----
20° C.:																		
Green Select 102	56	77	87	82	91	93	94	98	98	100	----	----	100	----	----	100	----	----
Rosen 82	40	53	72	47	76	79	81	92	93	94	95	96	98	98	98	99	99	99
Prolific 89	9	25	50	33	64	75	49	82	90	94	95	98	100	----	----	100	----	----
Emerald 92	72	91	95	99	100	----	100	----	----	100	----	----	100	----	----	100	----	----
30° C.:																		
Green Select 102	----	----	----	72	93	94	96	100	----	100	----	----	99	99	99	100	----	----
Rosen 82	----	----	----	71	87	88	96	100	----	100	----	----	99	99	99	100	----	----
Prolific 89	----	----	----	25	66	83	45	81	94	100	----	----	100	----	----	98	99	99
Emerald 92	----	----	----	97	99	99	99	99	99	100	----	----	99	99	99	100	----	----
35° C.:																		
Green Select 102	----	----	----	76	90	94	82	97	97	100	----	----	100	----	----	99	99	99
Rosen 82	----	----	----	53	78	77	81	91	95	97	97	97	96	98	98	99	99	99
Prolific 89	----	----	----	15	46	66	78	90	94	100	----	----	100	----	----	100	----	----
Emerald 92	----	----	----	94	98	98	100	----	----	100	----	----	99	99	99	100	----	----

[1] The first test was made July 8, second test July 15, third test July 22, fourth test July 29, fifth test Aug. 5, and sixth test Aug. 12.

[2] Collected July 11. Spring variety.

[3] The first test was made July 20, second test July 28, third test Aug. 3, fourth test Aug. 10, fifth test Aug. 17, and sixth test Aug. 24.

TABLE 7.—*Percentages of germination of early and late oat varieties harvested at different stages of maturity and stored at different temperatures, 1929*

[100 seeds taken for each test]

EARLY VARIETIES

Storage temperature and variety	Germination at soft-dough stage [1] after storage for indicated number of days						Germination at hard-dough stage [2] after storage for indicated number of days						Germination at ripe stage [3] after storage for indicated number of days					
	First test [4]		Second test [5]		Third test [6]		First test [4]		Second test [5]		Third test [6]		First test [4]		Second test [5]		Third test [6]	
	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
0° C.:																		
Double Cross 730																		
Minrus 693																		
Rainbow 710																		
Gopher 674	29	62	60	88	85	93							78	90	71	93		
North Dakota 22005	11	21	0	16	45	58	2	23	4	39	66	75	0	12	0	40	93	95
Iogold 711	0	15	5	36	62	84							1	9	2	12	73	87
Liberty Hull less 676	27	42	51	69	58	66							52	64	41	68	99	
10° C.:																		
Double Cross 730																		
Minrus 693																		
Rainbow 710																		
Gopher 674	20	45	39	59	72	77							7	47	47	77		
North Dakota 22005	0	0	0	12			0	10	10	48			9	36	10	74	100	
Iogold 711	1	3	0	8	57	65							2	19	11	44		
Liberty Hull-less 676	10	24	39	68											75	88	62	81
20° C.:																		
Double Cross 730																		
Minrus 693																		
Rainbow 710																		
Gopher 674	21	67	63	64	84								79	94	95	95		
North Dakota 22005	21	50	89	95			8	29	91	99			16	52	99	100		
Iogold 711	13	25	49	66	77	79							47	70	80	84		
Liberty Hull-less 676	65	89	98										95	98	100			

LATE VARIETIES

0° C.:																		
Anthony 686	0	13	2	20	61	77	0	19	3	13	39	76	6	30	0	6	63	79
Green Russian 713							5	24	32	63	49	70	22	47	37	62	98	
Green Russian 677	33	59	63	79			27	60	59	84			44	56	56	71	95	99
White Russian × Victory 696																		
Minota 512	2	16	4	37	9	41	3	20	5	41	88	92	9	22	1	31	85	90
Victory 514	8	24	1	28	6	28	5	29	1	20	65	84	14	55	20	54	77	83
North Dakota 20014	1	2	0	3	84	91	2	12	1	5	39	58	1	2	0	3	84	94
10° C.:																		
Anthony 686	0	5	0	5			0	5	0	5			4	15	5	19	94	95
Green Russian 713	2	14	0	46			36	70	6	27	82	86	27	65	62	80		
Green Russian 677	7	9	6	23			20	70	17	55			38	68	38	80		
White Russian × Victory 696																		
Minota 512	0	3	0	5			0	8	0	19			2	4	11	43	99	
Victory 514	1	30	1	37			2	21	6	29			12	72	26	70	98	
North Dakota 20014	0	2	2	8			0	0	0	0	58	66	0	1	12	27		
20° C.:																		
Anthony 686	36	53	96	97			3	7	48	83			1	11	73	76		
Green Russian 713	38	78	89	94			7	68	65	89			43	82	95	97		
Green Russian 677	42	55	59	61			45	97	76	79			53	66	94	96		
White Russian × Victory 696																		
Minota 512	22	70	92	99			13	42	90	97			15	44	94	97		
Victory 514	32	70	92	94			10	54	65	98			21	89	86	91		
North Dakota 20014	0	10	40	43	92		0	9	41	65	98		0	17	93	97		

[1] Early varieties collected July 18; late varieties July 24.
[2] Early varieties collected July 23; late varieties July 29.
[3] Early varieties collected July 26; late varieties Aug. 1.
[4] Begun Aug. 7, ended Aug. 14.
[5] Begun Aug. 30, ended Sept. 6.
[6] Begun Sept. 23, ended Sept. 30.

TABLE 8.—*Percentages of germination of early and late oat varieties harvested at different stages of maturity and stored at different temperatures, 1930*

[50 seeds taken for each test]

EARLY VARIETIES

Storage temperature and variety	Germination at soft-dough stage [1] after storage for indicated number of days									Germination at hard-dough stage [2] after storage for indicated number of days									Germination at ripe stage [3] after storage for indicated number of days								
	First test [4]			Second test [5]			Third test [6]			First test [7]			Second test [8]			Third test [9]			First test [10]			Second test [11]			Third test [12]		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																											
Double Cross 730	0	0	4	0	0	24	0	6	22	0	30	70	54	80	86	12	78	84	0	64	78	12	58	74	38	100	----
Minrus 693	0	4	26	0	0	44	22	54	76	0	18	32	66	78	86	76	92	98	0	32	74	26	52	90	100	----	----
Rainbow 710	0	0	0	0	0	6	0	10	18	0	0	6	6	30	40	14	50	62	0	22	78	46	84	94	100	----	----
Gopher 674	0	14	50	0	4	50	22	60	76	0	60	76	82	92	96	88	96	96	90	100	----	100	----	----	100	----	----
North Dakota 22005	0	0	2	0	0	2	2	4	20	0	0	14	4	34	54	6	44	58	0	16	66	72	96	98	98	100	----
Iogold 711	0	0	0	0	0	2	2	6	8	0	0	4	22	52	58	24	68	70	0	22	76	62	76	84	96	96	98
Liberty Hull-less 676	0	30	56	0	58	90	92	94	96	0	48	88	98	98	98	100	----	----	38	96	98	100	----	----	100	----	----
7° C.:																											
Double Cross 730	0	4	4	0	14	28	66	76	86	2	50	78	92	92	92	78	96	96	0	76	94	98	98	98	94	100	----
Minrus 693	0	20	28	0	10	38	82	88	98	0	8	32	86	90	100	90	98	98	0	38	84	80	90	98	94	100	----
Rainbow 710	0	0	0	0	0	4	50	56	72	0	0	26	62	70	86	58	88	94	20	68	88	90	96	96	100	----	----
Gopher 674	0	12	46	4	24	70	86	90	90	4	30	46	94	96	98	88	96	98	90	98	100	98	98	98	100	----	----
North Dakota 22005	0	0	0	0	0	4	14	28	48	0	0	34	62	70	84	62	82	88	2	74	90	98	100	----	100	----	----
Iogold 711	0	0	0	0	0	8	68	72	74	0	8	32	88	90	90	78	94	94	4	86	92	98	100	----	100	----	----
Liberty Hull-less 676	8	24	38	60	78	94	100	----	----	8	48	86	100	----	----	100	----	----	66	100	----	100	----	----	100	----	----
14° C.:																											
Double Cross 730	0	4	16	50	76	84	88	96	96	26	84	90	100	----	----	88	96	96	54	98	98	100	----	----	90	100	----
Minrus 693	0	30	52	40	80	94	84	90	90	20	64	82	94	96	98	88	100	----	18	92	100	100	----	----	82	100	----
Rainbow 710	0	2	8	10	36	88	70	86	92	0	24	56	100	----	----	90	100	----	38	100	----	100	----	----	100	----	----
Gopher 674	40	74	80	82	86	86	92	92	92	60	68	74	98	98	98	94	94	96	98	100	----	100	----	----	100	----	----
North Dakota 22005	0	0	14	56	84	88	88	98	98	2	56	70	98	98	98	80	98	98	60	98	98	100	----	----	100	----	----
Iogold 711	0	0	6	30	40	44	90	92	92	2	28	42	96	96	96	100	----	----	38	100	----	100	----	----	100	----	----
Liberty Hull-less 676	82	86	88	96	96	96	100	----	----	76	94	98	100	----	----	100	----	----	98	98	98	100	----	----	100	----	----

LATE VARIETIES

0° C.:																										
Anthony 686	0	0	0	0	2	10	0	18	20	0	0	14	96	96	98	96	96	96	34	78	82	64	84	86	100	.....	.....
Green Russian 713	0	0	0	0	62	74	14	56	70	0	10	42	100	.....	.....	100	.....	.....	10	70	80	42	70	76	100	.....	.....
Green Russian 677	0	8	46	28	88	90	26	88	88	12	58	76	100	.....	.....	96	96	96	14	78	80	78	86	90	100	.....	.....
White Russian × Victory 696	0	0	0	0	46	62	10	70	72	0	6	18	94	98	98	98	100	.....	22	70	70	38	56	70	100	.....	.....
Minota 512	0	0	0	4	40	62	30	74	74	0	12	56	100	.....	.....	98	98	98	70	98	98	88	92	92	100	.....	.....
Victory 514	0	0	2	0	40	54	4	72	78	0	8	48	100	.....	.....	100	.....	.....	2	78	82	14	30	70	80	86	86
North Dakota 20014	0	0	0	0	2	6	6	28	32	0	2	2	100	.....	.....	96	98	100	6	78	80	24	52	74	100	.....	.....
7° C.:																										
Anthony 686	0	0	0	0	54	66	44	78	80	0	22	46	98	100	.....	100	.....	.....	54	98	98	88	96	98	98	98	98
Green Russian 713	0	0	0	0	60	62	46	82	82	0	30	70	98	100	.....	100	.....	.....	64	98	100	90	96	98	100	.....	.....
Green Russian 677	0	6	34	44	94	96	76	92	92	14	80	92	100	.....	.....	100	.....	.....	80	100	.....	92	94	96	100	.....	.....
White Russian × Victory 696	0	0	0	6	64	80	24	76	82	0	18	36	96	100	.....	98	98	98	48	100	.....	72	86	100	98	98	98
Minota 512	0	0	0	18	80	86	76	90	92	12	44	70	98	98	98	98	98	100	76	96	96	100	.....	.....	100	.....	.....
Victory 514	0	0	0	12	62	70	26	74	78	0	28	66	86	92	92	92	98	100	18	92	92	60	82	90	96	100	.....
North Dakota 20014	0	0	0	4	34	44	54	78	86	0	0	0	74	80	94	94	100	.....	8	96	96	86	92	98	96	96	96
14° C.:																										
Anthony 686	0	0	12	90	96	98	64	98	98	50	94	98	98	100	.....	100	.....	.....	92	100	.....	90	98	98	96	96	96
Green Russian 713	0	0	28	66	84	84	54	90	92	28	80	88	100	.....	.....	100	.....	.....	98	100	.....	96	100	.....	100	.....	.....
Green Russian 677	0	10	46	70	92	92	46	92	94	70	96	96	100	.....	.....	100	.....	.....	98	100	.....	94	94	94	100	.....	.....
White Russian × Victory 696	0	2	32	50	96	100	50	92	92	24	72	86	90	94	96	86	90	94	94	100	.....	88	100	.....	100	.....	.....
Minota 512	0	2	50	92	100	.....	62	94	98	80	92	94	96	98	100	98	98	98	96	96	96	100	.....	.....	98	98	98
Victory 514	0	0	50	80	94	94	46	88	94	10	82	92	98	100	.....	100	.....	.....	92	100	.....	94	98	98	100	.....	.....
North Dakota 20014	0	0	2	76	92	94	54	90	92	4	28	64	94	94	94	100	.....	.....	88	96	96	96	100	.....	98	98	98

[1] Early varieties collected July 9; late varieties July 17.
[2] Early varieties collected July 14; late varieties July 21.
[3] Early varieties collected July 21; late varieties July 23.
[4] Early varieties, begun Aug. 2, ended Aug. 9; late varieties begun Aug. 6, ended Aug. 13.
[5] Early varieties, begun Aug. 23, ended Aug. 30; late varieties, begun Aug. 30, ended Sept. 6.
[6] Early varieties, begun Sept. 18, ended Sept. 25; late varieties, begun Sept. 19, ended Sept. 26.
[7] Begun Aug. 9, ended Aug. 16.
[8] Begun Sept. 4, ended Sept. 11.
[9] Early varieties, begun Sept. 24, ended Oct. 1; late varieties, begun Sept. 25, ended Oct. 2.
[10] Early varieties, begun Aug. 16, ended Aug. 23; late varieties, begun Aug. 19, ended Aug. 26.
[11] Begun Sept. 10, ended Sept. 17.
[12] Early varieties, begun Oct. 1, ended Oct. 8; late varieties, begun Oct. 2, ended Oct. 9.

TABLE 9.—*Germination percentages of early oat varieties harvested at different dates and stored at different temperatures, 1931*

[100 seeds taken for each test]

HARD-DOUGH STAGE, COLLECTED JULY 11 [1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Double Cross 730	----	----	----	1	2	3	0	4	27	1	5	32	1	2	6	1	7	22
Minrus 693	----	----	----	0	2	18	0	0	21	1	2	26	0	1	15	0	6	25
Gopher 674 [2]	----	----	----	40	89	92	14	72	81	39	78	86	76	79	84	57	89	92
Iogold 711 [2]	----	----	----	0	0	2	0	4	39	1	2	46	6	14	36	6	46	55
10° C.:																		
Double Cross 730	----	----	----	0	4	5	0	0	5	2	12	35	3	8	16	5	36	49
Minrus 693	----	----	----	0	4	11	0	3	9	5	36	53	24	39	58	8	79	81
Gopher 674 [2]	----	----	----	40	80	90	31	86	91	55	90	93	87	95	99	56	95	96
Iogold 711 [2]	----	----	----	0	2	10	1	8	33	3	46	48	38	54	56	54	77	81
20° C.:																		
Double Cross 730	6	10	21	2	8	17	5	28	45	57	74	87	68	73	85	94	99	99
Minrus 693	8	25	47	7	42	61	6	53	70	28	67	76	76	85	90	55	93	94
Gopher 674 [2]	48	82	86	60	90	98	85	91	93	88	93	93	97	98	98	95	99	99
Iogold 711 [2]	0	7	24	0	20	43	15	53	69	73	88	89	87	91	96	88	98	98
30° C.:																		
Double Cross 730	----	----	----	20	69	74	74	95	99	89	97	99	100	----	----	92	98	98
Minrus 693	----	----	----	21	54	69	25	88	91	53	89	94	96	96	97	72	97	97
Gopher 674 [2]	----	----	----	42	84	93	92	98	99	93	98	98	100	----	----	96	98	99
Iogold 711 [2]	----	----	----	52	68	79	73	89	94	83	97	99	98	98	98	84	99	100
35° C.:																		
Double Cross 730	----	----	----	13	52	61	81	89	93	94	100	----	100	----	----	98	100	----
Minrus 693	----	----	----	15	36	49	23	84	91	79	99	99	94	99	99	64	92	95
Gopher 674 [2]	----	----	----	40	75	80	83	93	95	92	100	----	100	----	----	92	98	98
Iogold 711 [2]	----	----	----	68	89	95	69	95	98	91	97	100	99	100	----	91	99	99

RIPE STAGE, COLLECTED JULY 22 [3]

0° C.:																		
Double Cross 730	----	----	----	34	67	68	12	55	77	23	75	81	43	88	94	77	94	96
Minrus 693	----	----	----	7	56	63	4	52	77	16	77	86	28	83	90	69	90	93
Gopher 674 [2]	----	----	----	96	99	99	81	98	98	93	98	98	93	95	96	92	97	97
Iogold 711 [2]	----	----	----	42	73	79	39	84	91	69	93	93	88	99	99	88	95	95
10° C.:																		
Double Cross 730	----	----	----	28	51	54	5	44	85	31	86	90	62	90	93	92	96	96
Minrus 693	----	----	----	16	53	68	2	38	67	19	83	87	41	90	90	83	99	99
Gopher 674 [2]	----	----	----	84	86	88	83	95	95	96	98	99	90	95	96	88	92	92
Iogold 711 [2]	----	----	----	42	74	80	15	72	80	82	98	98	88	96	96	92	95	96
20° C.:																		
Double Cross 730	1	21	25	46	78	80	74	92	93	89	99	100	98	99	99	100	----	----
Minrus 693	0	11	35	29	79	82	32	92	96	63	100	----	91	100	----	93	95	95
Gopher 674 [2]	74	97	99	2	17	22	98	99	99	97	98	98	100	----	----	93	98	99
Iogold 711 [2]	1	40	50	0	2	5	90	96	96	90	94	94	83	99	99	96	97	97
30° C.:																		
Double Cross 730	----	----	----	89	96	96	95	98	98	100	----	----	98	100	----	100	----	----
Minrus 693	----	----	----	72	99	99	73	100	----	90	100	----	95	99	99	86	98	98
Gopher 674 [2]	----	----	----	100	----	----	96	99	100	98	99	99	97	97	97	98	100	----
Iogold 711 [2]	----	----	----	87	96	96	97	99	99	100	----	----	100	----	----	96	99	99
35° C.:																		
Double Cross 730	----	----	----	96	97	97	99	99	99	98	100	----	99	100	----	100	----	----
Minrus 693	----	----	----	76	93	95	94	98	99	96	99	99	95	100	----	92	98	98
Gopher 674 [2]	----	----	----	100	----	----	96	97	98	93	100	----	94	97	97	90	96	97
Iogold 711 [2]	----	----	----	88	98	98	97	100	----	99	100	----	99	100	----	96	99	99

[1] The first test was made July 11, second test July 18, third test July 25, fourth test Aug. 1, fifth test Aug. 8, sixth test Aug. 15.

[2] Collected July 8.

[3] The first test was made July 22, second test July 30, third test Aug. 5, fourth test Aug. 12, fifth test Aug. 19, and sixth test Aug. 26.

TABLE 10.—*Germination percentages of late oat varieties harvested at different dates and stored at different temperatures, 1931*

[100 seeds taken for each test]

HARD-DOUGH STAGE, COLLECTED JULY 13[1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Anthony 686	----	----	----	0	0	1	0	1	20	0	0	2	0	2	11	0	2	7
Russian Green 713	----	----	----	0	15	24	1	42	55	0	6	30	0	5	39	0	13	55
Victory 514	----	----	----	0	7	17	0	21	42	0	0	14	0	2	7	0	3	21
North Dakota 20014	----	----	----	0	0	2	0	0	1	0	0	0	0	0	1	9	9	16
10° C.:																		
Anthony 686	----	----	----	0	0	0	0	5	7	1	4	10	1	12	28	0	40	58
Russian Green 713	----	----	----	1	4	6	2	28	62	2	31	46	3	41	52	15	77	87
Victory 514	----	----	----	0	0	0	0	8	22	0	4	20	1	8	26	9	48	60
North Dakota 20014	----	----	----	0	0	0	0	0	8	0	1	3	1	10	21	6	49	57
20° C.:																		
Anthony 686	0	2	16	0	0	0	0	7	26	0	9	35	1	38	65	24	80	89
Russian Green 713	0	4	23	4	20	26	6	43	71	5	59	73	12	68	76	44	89	92
Victory 514	0	4	18	0	2	14	0	11	36	1	28	42	34	77	83	66	95	98
North Dakota 20014	0	0	1	0	0	0	0	0	5	0	7	21	2	38	46	41	83	89
30° C.:																		
Anthony 686	----	----	----	14	70	81	43	79	85	63	86	86	95	99	99	96	99	99
Russian Green 713	----	----	----	27	75	83	77	94	94	77	94	95	88	100	----	88	98	99
Victory 514	----	----	----	0	14	51	45	82	88	50	55	56	96	99	99	95	99	99
North Dakota 20014	----	----	----	0	6	13	23	70	79	71	89	90	94	99	99	92	100	----
35° C.:																		
Anthony 686	----	----	----	12	74	76	78	89	90	73	91	91	78	97	97	96	100	----
Russian Green 713	----	----	----	13	69	78	50	96	98	73	97	97	66	100	----	84	97	98
Victory 514	----	----	----	8	50	60	67	91	93	53	91	93	78	91	92	77	97	97
North Dakota 20014	----	----	----	16	37	50	64	86	87	64	92	95	81	92	93	94	99	99

[1] The first test was made July 13, second test July 20, third test July 28, fourth test Aug. 3, fifth test Aug. 10, and sixth test Aug. 17.

TABLE 10.—*Germination percentages of late oat varieties harvested at different dates and stored at different temperatures, 1931*—Continued

[100 seeds taken for each test]

RIPE STAGE, COLLECTED JULY 22 [1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Anthony 686	----	----	----	0	6	13	0	5	29	9	59	67	4	56	74	30	86	91
Russian Green 713	----	----	----	6	38	48	0	22	67	6	71	80	9	68	87	31	84	88
Victory 514	----	----	----	1	4	11	0	8	41	3	63	75	5	66	79	11	83	88
North Dakota 20014	----	----	----	0	0	3	0	2	7	0	6	19	1	10	34	5	58	72
10° C.:																		
Anthony 686	----	----	----	0	25	32	0	36	60	12	73	77	19	80	85	29	93	96
Russian Green 713	----	----	----	3	51	61	4	60	92	8	84	90	37	94	97	80	99	99
Victory 514	----	----	----	0	7	15	0	9	34	6	77	84	8	81	88	28	97	99
North Dakota 20014	----	----	----	0	1	3	0	8	17	0	47	60	9	64	74	41	84	86
20° C.:																		
Anthony 686	0	9	19	2	37	43	11	81	89	82	95	95	82	99	99	84	94	95
Russian Green 713	1	30	57	5	71	75	12	79	87	77	95	96	77	97	99	98	100	----
Victory 514	0	3	11	97	99	99	0	38	62	36	96	97	79	100	----	92	98	98
North Dakota 20014	0	0	0	59	74	81	0	17	58	43	96	96	74	93	94	92	94	96
30° C.:																		
Anthony 686	----	----	----	82	87	88	82	97	98	85	88	89	99	100	----	98	100	----
Russian Green 713	----	----	----	75	95	97	80	100	----	97	100	----	97	100	----	98	100	----
Victory 514	----	----	----	70	95	96	92	98	98	85	95	95	85	100	----	92	99	99
North Dakota 20014	----	----	----	39	80	85	62	96	97	98	99	99	90	98	99	93	100	----
35° C.:																		
Anthony 686	----	----	----	92	95	95	62	92	94	90	97	97	96	98	98	88	98	98
Russian Green 713	----	----	----	74	94	97	85	99	99	95	100	----	100	----	----	98	100	----
Victory 514	----	----	----	81	91	91	92	97	97	97	100	----	99	100	----	93	100	----
North Dakota 20014	----	----	----	24	85	95	93	99	100	98	100	----	99	100	----	99	100	----

[1] The first test was made July 22, second test July 30, third test Aug. 5, fourth test Aug. 12, fifth test Aug. 19, and sixth test Aug. 26.

TABLE 11.—*Percentages of germination of winter and spring wheat varieties harvested at different stages of maturity and stored at different temperatures, 1929*

[100 seeds taken for each test]

WINTER VARIETIES

Storage temperature and variety	Germination at soft-dough stage [1] after storage for indicated number of days						Germination at hard-dough stage [2] after storage for indicated number of days						Germination at ripe stage [3] after storage for indicated number of days					
	First test [4]		Second test [5]		Third test [6]		First test [4]		Second test [5]		Third test [6]		First test [4]		Second test [5]		Third test [6]	
	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
0° C.:																		
Iobred 1949	2	3	0	4	0	1	8	9	7	26	11	18	4	7	11	38	15	23
Kanred 2191	2	11	0	25	1	15	49	70	36	74	66	86	2	0	3	28	9	29
Turkey 1488	12	33	2	40			60	93	88	99			60	70	85	99		
Minturki 1507	6	14	19	86			87	95	97	99			58	74	100	100		
Crimean 845	15	30	11	49			56	72	51	79			9	13	87	95		
Ukrianka 2299	23	38	1	34	4	20	0	0	9	29	12	24	27	36	13	50	16	37
Minhardi 1505	2	11	0	10	1	28	18	44	15	68	12	23	9	14	1	8	5	19
Minard 2199	11	22	2	42	15	37	11	23	11	57	10	39	20	29	24	67	9	33
Red Rock 2154	32	47	8	49	7	36	39	63	8	49			28	81	44	94		
Marquis 1239	0	11	6	73	10	88	18	30	8	22	9	27	7	12	13	19	60	85
10° C.:																		
Iobred 1949	0	0	2	3			2	0	19	35	11	24	11	25	82	90		
Kanred 2191	0	1	1	2	9	16	15	27	82	91			4	9	78	94	84	97
Turkey 1488	1	3	17	46			53	74	96	98			80	84	94	94		
Minturki 1507	12	29	86	98			90	95	100	100			98	100	100	100		
Crimean 845	1	4	53	74	75	76	18	25	73	84	75	76	71	77	94	99		
Ukrianka 2299	1	1	3	10			1	2	27	42	67	75	2	10	87	92	75	98
Minhardi 1505	0	2	1	10	0	37	5	12	67	84			1	3	48	63	9	32
Minard 2199	0	0	29	60			8	12	62	82			60	84	99	99		
Red Rock 2154	0	1	14	65			24	38	89	93			78	86	100	100		
Marquis 1239	1	1	2	9	100	100	1	1	18	31			17	30	98	98		

[1] Winter varieties collected July 5; spring varieties, July 19.
[2] Winter varieties collected July 11; spring varieties, July 24.
[3] Winter varieties collected July 15; spring varieties, July 28.
[4] Winter varieties, begun Aug. 16, ended Aug. 23; spring varieties, begun Aug. 22, ended Aug. 29.
[5] Winter varieties, begun Sept. 14, ended Sept. 21; spring varieties, begun Sept. 16, ended Sept. 23.
[6] Winter varieties, begun Sept. 28, ended Oct. 5; spring varieties, begun Oct. 14, ended Oct. 21.

TABLE 11.—*Percentages of germination of winter and spring wheat varieties harvested at different stages of maturity and stored at different temperatures, 1929*—Continued

[100 seeds taken for each test]

WINTER VARIETIES—Continued

Storage temperature and variety	Germination at soft-dough stage after storage for indicated number of days						Germination at hard-dough stage after storage for indicated number of days						Germination at ripe stage after storage for indicated number of days					
	First test		Second test		Third test		First test		Second test		Third test		First test		Second test		Third test	
	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
20° C.:																		
Iobred 1949	2	5	5	26	.....	.....	3	7	6	45	.....	.....	0	3	32	72	75	86
Kanred 2191	1	1	10	36	.....	.....	3	7	19	75	.....	.....	4	12	38	67	55	65
Turkey 1488	55	92	98	99	.....	.....	100	100	98	98	.....	.....	96	100	96	100	.....	.....
Minturki 1507	98	99	99	99	.....	.....	98	100	99	99	.....	.....	94	98	72	88	.....	.....
Crimean 845	45	63	94	98	.....	.....	76	88	91	95	.....	.....	81	92	100	100	.....	.....
Ukrianka 2299	77	82	70	92	.....	.....	1	4	27	93	.....	.....	13	21	67	91	.....	.....
Minhardi 1505	3	11	10	57	.....	.....	9	15	29	68	59	87	2	3	26	67	64	84
Minard 2199	95	98	99	99	.....	.....	28	40	64	78	17	33	18	28	79	90	.....	.....
Red Rock 2154	92	96	77	98	.....	.....	76	83	97	100	.....	.....	74	91	99	99	.....	.....
Marquis 1239	0	2	77	85	.....	.....	4	23	98	98	.....	.....	3	10	98	98	.....	.....
SPRING VARIETIES																		
0° C.:																		
Nodak 2311	0	0	2	23	4	26	2	10	6	31	18	37	24	32	58	77	73	94
Marquis 1239	0	11	6	73	10	88	18	30	8	22	9	27	7	12	13	19	60	85
Double Cross 2305	.....	.....	.....	.....	.....	.....	0	5	6	32	5	45	.....	.....	.....	.....	.....	.....
Mindum 470	0	2	0	2	0	15	2	5	3	15	29	62	52	61	38	61	76	93
Marquillo 2202	1	2	0	1	0	8	6	10	3	10	0	6	1	1	0	4	4	33
Reward 2204	0	0	0	0	7	50	2	2	1	1	11	24	5	6	3	4	70	92
Hope 2297	3	19	0	51	11	34	1	3	1	5	30	84	0	0	1	1	23	30
Double Cross 2304	.....	.....	.....	.....	.....	.....	0	1	0	22	2	39	.....	.....	.....	.....	.....	.....
Double Cross 2303	.....	.....	.....	.....	.....	.....	9	16	3	18	63	91	3	6	13	37	59	91
Kubanka 2310	0	16	0	23	3	7	7	16	0	36	1	31	63	78	50	88	.....	.....
Marquis × Einkorn 2301	.....	.....	.....	.....	.....	.....	0	2	1	8	35	69	0	0	2	5	4	12
Supreme 2309	19	63	29	91	.....	.....	2	31	51	87	.....	.....	11	22	54	66	99	99
Bluestem 169	4	20	6	27	0	4	0	0	0	5	0	1	.....	.....	.....	.....	.....	.....
Ceres 2223	0	4	2	50	7	55	5	5	12	71	54	95	0	4	2	9	31	52
Reliance 2308	3	33	6	28	24	74	2	13	39	81	.....	.....	1	2	20	28	44	59

10° C.:																		
Nodak 2311	0	0	3	8			3	8					1	18	25	64		
Marquis 1239	1	1	2	9	100	100	1	1	18	31			17	30	98	98		
Double Cross 2305							0	0	0	7								
Mindum 470	1	1	3	4			0	0	1	18			4	27	45	62		
Marquillo 2202	0	0	0	0			0	0	4	15			2	2	16	37	96	98
Reward 2204	1	2	8	30			0	9	48	70			8	11	81	96		
Hope 2297	0	1	1	10			0	0	8	12			0	0	8	27		
Double Cross 2304							0	0	2	3								
Double Cross 2303							1	3	3	16			1	3	49	56	96	97
Kubanka 2310	3	3	5	9			3	9	0	15			14	53	39	89		
Marquis × Einkorn 2301							0	0	0	2			1	3	24	50		
Supreme 2309	2	16	22	47			0	4	77	82			61	72	97	99		
Bluestem 169	0	0	5	18			0	0	4	5								
Ceres 2223	0	0	23	54			0	3	37	48			12	29	86	97		
Reliance 2308	2	2	15	30			1	1	10	16	99	99	2	13	82	87		
20° C.:																		
Nodak 2311	0	1	35	71	14	78	0	20	78	91			0	12	55	71	26	89
Marquis 1239	0	2	77	85			4	23	97	97			3	10	98	98		
Double Cross 2305							0	0	10	20	25	43						
Mindum 470	9	28	31	67	36	76	5	61	48	95			1	27	5	46	5	64
Marquillo 2202	15	15	4	7	32	45	0	0	2	20			0	2	33	51		
Reward 2204	24	66	86	97			8	48	97	97			4	8	96	100		
Hope 2297	2	14	90	93			1	3	61	68	90	93	0	0	48	53	71	81
Double Cross 2304							0	2	7	12	27	57						
Double Cross 2303							0	6	65	71	90	93	0	2	84	86		
Kubanka 2310	0	37	38	57	64	94	7	57	66	91			30	72	69	95		
Marquis × Einkorn 2301							3	11	92	97			1	3	85	90		
Supreme 2309	34	56	87	91			26	53	95	96			42	52	80	80		
Bluestem 169	14	17	52	62	95	95	0	0	95	95								
Ceres 2223	20	58	99	99			8	35	100	100			11	29	94	95		
Reliance 2308	2	7	83	85			0	4	94	95			3	13	95	95		

TABLE 12.—*Percentages of germination of winter and spring wheat varieties harvested at different stages of maturity and stored at different temperatures, 1930*

[50 seeds taken for each test]

WINTER VARIETIES

Storage temperature and variety	Germination at soft-dough stage [1] after storage for indicated number of days									Germination at hard-dough stage [2] after storage for indicated number of days									Germination at ripe stage [3] after storage for indicated number of days								
	First test [4]			Second test [5]			Third test [6]			First test [7]			Second test [8]			Third test [9]			First test [10]			Second test [11]			Third test [12]		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																											
Minturki 1507	0	26	62	0	10	62	0	12	60	0	6	16	10	76	90	62	94	96	66	70	82	92	98	100	98	98	98
Marquis 1239	0	0	0	0	4	8	0	0	10	0	0	0	0	0	0	0	0	8	0	0	0	0	0	4	16	54	60
Minhardi 1505	0	10	14	0	0	4	0	8	74	0	0	2	0	54	78	6	74	92	2	2	10	44	50	56	80	88	88
Minard 2199	2	18	30	0	8	24	0	8	38	0	0	2	0	24	28	16	50	70	4	4	10	22	42	56	82	88	98
Minard × Minhardi 2314	2	6	16	0	2	8	0	0	50	0	0	2	0	14	22	18	64	90	0	0	0	16	44	60	66	84	92
Minard × Minhardi 2313	0	0	12	0	0	16	0	12	62	0	2	2	2	28	42	6	58	90	0	2	20	8	22	38	70	88	96
Minhardi × Minturki 2312	0	10	38	0	16	56	2	14	52	0	4	4	6	56	66	4	72	96	14	16	30	52	68	72	96	98	100
7° C.:																											
Minturki 1507	0	2	4	0	0	18	16	90	98	0	8	24	98	100	----	94	98	98	84	86	88	100	----	----	100	----	----
Marquis 1239	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	8	52	2	4	12	26	62	64	78	98	100
Minhardi 1505	0	0	0	0	0	2	2	10	22	0	0	2	6	70	82	20	80	92	0	0	4	48	66	82	98	98	98
Minard 2199	0	2	8	0	0	6	4	58	72	0	0	0	18	38	58	80	94	98	4	4	20	74	88	92	98	98	98
Minard × Minhardi 2314	0	0	0	0	0	0	0	0	2	0	0	0	6	54	64	38	88	92	0	2	30	36	72	78	84	88	96
Minard × Minhardi 2313	0	0	0	0	0	2	0	0	6	0	0	0	18	44	60	34	88	98	0	2	18	4	38	62	90	94	94
Minhardi × Minturki 2312	0	0	28	0	0	10	2	26	56	0	4	12	42	86	96	80	96	100	6	8	20	98	98	100	100	----	----
14° C.:																											
Minturki 1507	6	26	46	100	----	----	98	100	----	0	12	24	98	98	98	100	----	----	64	64	80	100	----	----	100	----	----
Marquis 1239	0	0	0	70	72	74	92	96	98	0	0	2	80	96	100	96	98	98	0	0	0	80	98	100	94	96	96
Minhardi 1505	0	0	0	10	18	36	60	98	100	0	2	4	84	98	98	100	----	----	4	4	6	90	100	----	100	----	----
Minard 2199	2	4	24	80	80	82	98	98	98	0	2	22	98	100	----	98	98	98	0	0	20	100	----	----	100	----	----
Minard × Minhardi 2314	0	0	0	0	6	6	62	82	86	0	0	0	100	----	----	98	98	98	0	0	4	28	86	88	100	----	----
Minard × Minhardi 2313	0	0	0	2	2	8	72	92	94	0	2	2	96	100	----	100	----	----	0	0	6	36	84	90	100	----	----
Minhardi × Minturki 2312	0	2	20	68	86	88	94	98	98	0	10	20	98	98	98	100	----	----	22	28	56	98	98	98	100	----	----

SPRING VARIETIES

0° C.:																												
Kubanka × Marquis 2224	0	0	2	0	0	10	0	0	12	0	0	0	0	0	4	18	36	46	0	2	2	2	6	12	10	14	16	
Kubanka × Marquis 2317	0	0	0	0	0	18	0	0	2	0	0	0	0	0	2	0	12	26	0	2	2	28	38	44	32	40	40	
Nodak 2311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	2	26	48	4	14	16	18	18	46	14	20	36	
Double Cross 2305	0	0	0	0	0	4	0	0	4	0	6	6	2	10	18	4	20	30	0	4	4	0	6	18	38	52	64	
Marquis 1239	0	0	0	0	0	8	0	0	0	0	6	12	2	8	10	6	34	50	0	2	2	0	22	44	14	32	40	
Double Cross 2305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	2	0	0	0	0	0	4	0	0	0	
Mindum 470	0	0	0	0	0	0	0	0	6	0	4	4	0	0	18	0	8	38	0	0	0	0	0	32	0	0	8	
Double Cross 2316	0	0	0	0	0	6	0	0	2	0	2	6	0	0	2	0	18	44	0	0	2	6	28	44	18	26	36	
Marquillo 2202	0	0	2	0	0	6	0	0	2	0	0	0	0	0	0	0	4	14	0	0	0	18	18	20	0	0	4	
Kota × Marquis 2298	0	0	14	0	0	20	0	2	12	0	2	6	0	0	2	12	26	34	0	4	4	72	82	92	66	68	74	
Reward 2204	0	2	2	0	0	0	0	0	0	0	2	6	8	30	52	78	94	98	6	46	52	40	50	72	60	62	72	
Hope 2297	0	0	2	0	0	6	0	0	2	0	0	4	0	12	22	28	58	60	0	0	0	0	0	4	0	4	10	
Double Cross 2304	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0	0	6	0	0	0	
Double Cross 2303	0	0	0	0	0	20	0	0	12	0	0	0	0	0	2	2	26	36	0	0	0	0	0	4	4	4	4	
Kubanka 2310	0	0	0	0	0	0	0	0	0	0	2	6	0	2	22	0	8	30	0	20	36	2	34	68	8	16	44	
Marquis × Emmer 2301	0	0	2	0	2	2	0	0	6	0	0	0	0	0	16	24	38	46	0	0	4	10	10	12	2	4		
Supreme 2309	0	2	22	0	0	0	0	8	30	4	16	28	10	78	82	76	100	----	2	40	58	30	66	88	68	72	80	
Bluestem 169	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	4	0	0	0	0	12	30	4	8	14	
Ceres 2223	0	0	0	0	0	4	0	0	6	0	2	4	0	8	22	62	78	84	0	4	10	18	32	50	44	46	61	
Double Cross 2315	0	0	0	0	0	0	0	0	2	0	2	6	0	0	4	0	4	10	0	0	2	2	8	14	10	10	14	
Reliance 2308	0	0	4	0	0	28	0	24	50	0	6	14	0	4	26	16	44	62	0	0	2	34	62	72	38	40	52	
7° C.:																												
Kubanka × Marquis 2224	0	0	0	0	0	0	0	0	0	0	0	2	8	16	28	26	44	54	0	2	2	0	0	6	0	4	8	
Kubanka × Marquis 2317	0	0	0	0	0	2	0	0	0	0	0	0	0	8	24	38	48	54	0	0	0	8	14	30	24	34	38	
Nodak 2311	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	26	50	0	6	16	6	12	54	4	12	24	
Double Cross 2302	0	0	0	0	0	8	0	2	8	0	2	4	0	2	4	0	10	20	0	4	16	0	20	40	6	14	46	
Marquis 1239	0	0	0	0	0	0	0	0	6	0	0	0	6	58	72	82	94	96	0	0	0	0	4	12	6	8	10	
Double Cross 2305	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	2	6	0	4	14	0	0	4	2	4	6	
Mindum 470	0	0	0	0	0	0	0	0	0	0	0	2	0	0	8	0	0	20	0	0	0	0	2	40	0	0	6	
Double Cross 2316	0	0	2	0	0	12	0	0	0	0	0	0	0	4	8	0	6	24	0	0	0	0	0	10	0	0	8	
Marquillo 2202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	32	34	0	0	0	0	0	14	0	0	2	
Kubanka × Marquis 2298	0	0	0	0	0	0	0	0	0	0	0	2	10	32	38	52	58	62	0	4	6	22	46	62	40	44	48	
Reward 2204	0	0	4	0	0	0	0	0	2	0	2	20	74	96	98	100	----	----	18	54	56	56	76	94	62	64	68	
Hope 2297	0	0	0	0	0	0	0	2	4	0	0	0	56	78	84	96	98	98	0	0	0	0	0	2	2	2	2	
Double Cross 2304	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	
Double Cross 2303	0	0	0	0	0	6	0	22	56	0	0	0	0	36	62	64	84	88	0	0	2	2	16	28	2	12	20	

[1] Winter varieties collected July 7; spring varieties July 8.
[2] Winter varieties collected July 9; spring varieties July 14.
[3] Winter varieties collected July 17; spring varieties July 28.
[4] Winter varieties, begun July 29, ended Aug. 5; spring varieties, begun Aug. 8, ended Aug. 15.
[5] Winter varieties, begun Aug. 21, ended Aug. 28; spring varieties, begun Aug. 30, ended Sept. 6.
[6] Winter varieties, begun Sept. 17, ended Sept. 24; spring varieties, begun Sept. 19, ended Sept. 26.
[7] Winter varieties, begun Aug. 5, ended Aug. 12; spring varieties, begun Aug. 12, ended Aug. 19.
[8] Winter varieties, begun Sept. 2, ended Sept. 9; spring varieties, begun Sept. 6, ended Sept. 13.
[9] Winter varieties, begun Sept. 22, ended Sept. 29; spring varieties, begun Sept. 25, ended Oct. 2.
[10] Winter varieties, begun Aug. 14, ended Aug. 21; spring varieties, begun Aug. 20, ended Aug. 27.
[11] Winter varieties, begun Sept. 9, ended Sept. 16; spring varieties, begun Sept. 11, ended Sept. 18.
[12] Winter varieties, begun Sept. 27, ended Oct. 4; spring varieties, begun Oct. 2, ended Oct. 9.

TABLE 12.—*Percentages of germination of winter and spring wheat varieties harvested at different stages of maturity and stored at different temperatures, 1930*—Continued

[50 seeds taken for each test]

SPRING VARIETIES—Continued

Storage temperature and variety	Germination at soft-dough stage after storage for indicated number of days									Germination at hard-dough stage after storage for indicated number of days									Germination at ripe stage after storage for indicated number of days								
	First test			Second test			Third test			First test			Second test			Third test			First test			Second test			Third test		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
7° C.:—Continued																											
Kubanka 2310	0	0	0	0	0	0	0	2	4	0	10	22	4	24	76	4	64	80	0	38	58	2	46	88	4	22	68
Marquis × Emmer 2301	0	0	0	0	0	0	0	0	0	0	0	2	20	54	60	86	88	94	0	4	8	10	14	24	10	20	44
Supreme 2309	0	0	2	4	36	32	6	28	60	30	62	68	94	98	98	98	98	98	22	64	64	58	76	88	92	92	92
Bluestem 169	0	0	0	0	0	0	0	2	2	0	0	2	28	58	88	98	98	98	0	2	6	0	20	58	54	68	82
Ceres 2223	0	0	0	0	0	2	2	18	18	0	0	0	86	88	90	100	----	----	2	14	16	30	74	80	68	68	70
Double Cross 2315	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	6	14	0	0	0	0	4	10	2	2	14
Reliance 2308	0	0	0	0	0	16	0	12	36	0	2	2	70	94	94	94	98	98	0	0	4	28	58	76	62	64	68
14° C.:																											
Kubanka × Marquis 2224	0	0	0	6	12	16	46	62	68	0	0	0	76	82	82	100	----	----	0	4	14	86	94	94	98	98	98
Kubanka × Marquis 2317	0	0	0	0	4	12	50	58	74	0	0	2	74	84	84	100	----	----	0	12	20	100	----	----	98	98	98
Nodak 2311	0	0	0	0	10	12	2	18	20	0	20	32	34	92	96	100	----	----	6	56	78	14	80	92	94	96	100
Double Cross 2302	0	0	0	0	0	2	28	32	32	0	0	0	60	68	68	92	94	92	4	20	60	64	94	96	100	----	----
Marquis 1239	0	0	4	80	82	84	86	86	86	0	6	20	94	96	96	96	98	100	0	14	32	30	70	86	84	86	96
Double Cross 2305	0	2	6	8	10	10	6	12	20	0	0	2	14	30	48	84	88	92	0	0	2	12	70	98	54	68	94
Mindum 470	0	0	4	4	6	14	46	88	90	0	14	48	4	90	96	94	94	94	0	6	50	0	58	90	54	96	98
Double Cross 2316	0	0	0	0	4	8	2	6	20	0	0	2	20	48	58	96	96	96	0	8	28	94	100	----	100	----	----
Marquillo 2202	0	0	0	0	2	2	30	78	82	0	0	0	62	80	86	100	----	----	2	2	26	66	96	96	100	----	----
Kubanka × Marquis 2298	0	0	0	2	8	10	72	78	80	0	0	2	92	92	92	100	----	----	68	76	76	100	----	----	100	----	----
Reward 2204	0	0	2	92	94	94	94	100	----	14	66	92	94	100	----	100	----	----	70	98	98	96	100	----	98	98	98
Hope 2297	0	4	0	82	82	86	94	96	96	4	4	10	98	98	98	98	98	98	0	12	28	90	96	98	100	----	----
Double Cross 2304	0	0	0	0	0	0	2	4	10	0	0	0	6	40	48	88	88	88	0	4	4	62	88	98	88	94	6
Double Cross 2303	0	0	8	54	54	58	94	94	94	0	0	4	98	98	98	92	92	92	0	6	12	92	94	94	96	96	6
Kubanka 2310	0	0	0	2	10	28	0	14	30	0	70	90	38	92	100	96	98	98	0	86	98	10	94	94	98	98	98
Marquis × Emmer 2301	0	0	0	90	90	92	86	86	86	0	2	4	98	98	98	100	----	----	10	40	52	98	100	----	100	----	----
Supreme 2309	0	2	10	92	92	92	100	----	----	38	54	64	96	98	98	100	----	----	64	94	96	98	98	98	100	----	----
Bluestem 169	0	0	8	42	42	42	60	66	66	4	34	46	100	----	----	100	----	----	2	34	56	96	100	----	100	----	----
Ceres 2223	0	14	30	90	90	92	96	98	100	10	34	62	98	100	----	100	----	----	54	94	96	100	----	----	100	----	----
Double Cross 2315	0	0	4	4	10	20	16	48	66	0	4	8	16	44	56	100	----	----	2	10	38	90	96	100	100	----	----
Reliance 2308	0	6	20	84	84	86	88	90	90	12	34	46	94	94	94	100	----	----	66	82	86	100	----	----	100	----	----

TABLE 13.—*Germination percentages of winter wheat varieties harvested at different dates and stored at different temperatures, 1931*

[100 seeds taken for each test]

HARD-DOUGH STAGE, COLLECTED JULY 6[1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Minturki 1507	6	20	28	0	0	1	0	7	11	12	32	37	36	64	83	75	79	85
Minhardi 1505	1	9	14	0	0	2	0	0	0	0	0	2	1	7	21	10	21	32
Minard 2199	10	34	44	3	6	8	3	9	13	2	9	11	1	6	14	28	41	53
Minhardi × Minturki 2312	2	11	14	0	0	3	1	7	9	1	6	11	7	17	31	26	48	61
10° C.:																		
Minturki 1507	4	15	20	0	0	3	0	0	4	9	17	29	22	40	58	85	93	94
Minhardi 1505	0	4	10	0	0	0	0	0	2	3	4	12	1	3	7	13	35	41
Minard 2199	9	29	49	1	2	3	1	9	15	2	7	14	2	22	24	21	34	35
Minhardi × Minturki 2312	0	5	13	0	0	0	0	1	5	1	6	20	0	8	13	37	61	67
20° C.:																		
Minturki 1507	3	16	20	1	3	5	8	22	33	43	59	72	76	88	90	94	100	----
Minhardi 1505	3	11	14	0	0	2	0	2	2	1	4	10	2	6	20	33	61	67
Minard 2199	13	35	48	0	0	1	0	5	8	15	52	62	24	63	78	89	98	98
Minhardi × Minturki 2312	2	9	11	0	0	0	3	4	8	6	21	31	30	69	87	89	92	96
30° C.:																		
Minturki 1507	4	17	26	68	80	91	82	95	97	97	99	99	99	100	----	100	----	----
Minhardi 1505	4	13	21	0	5	12	8	45	59	86	96	99	95	100	----	98	100	----
Minard 2199	6	26	31	65	73	82	73	91	94	98	100	----	100	----	----	100	----	----
Minhardi × Minturki 2312	3	12	13	35	49	64	73	87	91	97	100	----	100	----	----	100	----	----
35° C.:																		
Minturki 1507	7	19	23	45	57	70	84	97	98	97	100	----	99	100	----	100	----	----
Minhardi 1505	0	4	5	0	5	9	5	53	68	92	99	99	98	100	----	97	97	97
Minard 2199	8	27	40	23	30	39	56	83	86	85	97	98	98	99	100	100	----	----
Minhardi × Minturki 2312	3	12	14	44	54	66	71	89	92	96	98	99	99	99	99	100	----	----

RIPE STAGE, COLLECTED JULY 16[2]

0° C.:																		
Minturki 1507	----	----	----	26	37	67	60	82	86	94	98	99	96	100	----	100	----	----
Minhardi 1505	----	----	----	0	0	2	2	3	8	6	24	34	2	14	39	33	59	60
Minard 2199	----	----	----	52	58	74	44	57	63	76	87	91	70	93	96	89	93	96
Minhardi × Minturki 2312	----	----	----	7	11	22	11	20	24	30	55	62	34	84	91	86	91	93
10° C.:																		
Minturki 1507	----	----	----	33	46	78	78	83	87	95	100	----	95	99	99	99	100	----
Minhardi 1505	----	----	----	0	1	13	0	0	2	6	14	22	1	15	33	47	56	58
Minard 2199	----	----	----	22	30	52	27	48	58	83	88	93	86	96	99	89	95	96
Minhardi × Minturki 2312	----	----	----	1	6	16	11	19	23	70	77	84	71	89	90	88	92	93
20° C.:																		
Minturki 1507	10	41	46	78	94	97	100	----	----	99	99	99	99	100	----	100	----	----
Minhardi 1505	0	3	15	4	13	25	4	12	13	33	69	74	55	91	94	90	93	95
Minard 2199	10	40	45	52	59	73	78	86	91	97	99	100	100	----	----	98	99	99
Minhardi × Minturki 2312	0	0	0	20	33	53	26	43	54	80	89	92	87	99	99	97	97	97
30° C.:																		
Minturki 1507	----	----	----	96	98	99	100	----	----	100	----	----	100	----	----	100	----	----
Minhardi 1505	----	----	----	3	11	26	62	78	82	100	----	----	100	----	----	100	----	----
Minard 2199	----	----	----	87	90	95	100	----	----	100	----	----	100	----	----	100	----	----
Minhardi × Minturki 2312	----	----	----	59	69	95	98	99	(?)	100	----	----	100	----	----	100	----	----
35° C.:																		
Minturki 1507	----	----	----	96	98	99	100	----	----	100	----	----	100	----	----	100	----	----
Minhardi 1505	----	----	----	3	14	40	83	89	92	100	----	----	100	----	----	100	----	----
Minard 2199	----	----	----	91	91	95	100	----	----	100	----	----	100	----	----	100	----	----
Minhardi × Minturki 2312	----	----	----	66	72	91	100	----	----	100	----	----	100	----	----	100	----	----

[1] The first test was made July 8, second test July 15, third test July 22, fourth test July 29, fifth test Aug. 5, and sixth test Aug. 12.

[2] The first test was made July 16, second test July 23, third test July 30, fourth test Aug. 6, fifth test Aug. 13, and sixth test Aug. 20.

TABLE 14.—*Germination percentages of spring wheat varieties harvested at different dates and stored at different temperatures, 1931*

[100 seeds taken for each test]

HARD-DOUGH STAGE, COLLECTED JULY 13 [1]

Storage temperature and variety	Germination in first test after storage for indicated number of days			Germination in second test after storage for indicated number of days			Germination in third test after storage for indicated number of days			Germination in fourth test after storage for indicated number of days			Germination in fifth test after storage for indicated number of days			Germination in sixth test after storage for indicated number of days		
	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7	3	5	7
0° C.:																		
Marquis 1239	----	----	----	0	0	0	0	0	0	0	2	3	0	0	3	0	3	11
Reward 2204	----	----	----	0	0	0	0	0	1	0	0	1	0	0	1	3	4	5
Kubanka 2310	----	----	----	19	33	36	0	22	44	0	10	42	1	18	45	0	1	44
Double Cross 2304	----	----	----	1	4	6	0	2	6	0	0	2	1	1	2	1	1	4
10° C.:																		
Marquis 1239	----	----	----	0	0	1	0	1	3	0	0	1	1	3	8	4	5	12
Reward 2204	----	----	----	0	1	2	1	1	3	0	1	2	1	4	6	0	2	7
Kubanka 2310	----	----	----	0	15	15	0	9	35	0	6	52	0	7	44	0	5	34
Double Cross 2304	----	----	----	0	6	7	0	3	7	0	1	4	0	0	2	0	0	13
20° C.:																		
Marquis 1239	0	2	8	0	0	2	0	0	2	0	0	2	4	16	35	28	42	58
Reward 2204	0	0	0	3	3	3	0	0	1	0	1	3	11	41	62	53	73	89
Kubanka 2310	0	15	42	0	2	5	0	2	20	0	2	30	1	2	24	10	11	30
Double Cross 2304	0	4	16	1	1	1	0	0	0	0	0	0	2	2	2	0	1	2
30° C.:																		
Marquis 1239	----	----	----	0	0	2	0	4	10	8	32	57	51	90	92	74	91	95
Reward 2204	----	----	----	4	8	11	21	51	58	67	90	98	95	97	97	96	98	100
Kubanka 2310	----	----	----	0	9	35	1	53	83	0	78	96	16	100	----	99	99	99
Double Cross 2304	----	----	----	0	0	1	0	9	19	4	13	36	11	91	95	92	100	----
35° C.:																		
Marquis 1239	----	----	----	0	2	3	2	13	26	32	55	69	46	84	94	74	83	96
Reward 2204	----	----	----	1	2	5	35	72	78	79	88	89	95	97	98	95	96	98
Kubanka 2310	----	----	----	0	23	65	0	58	92	2	91	100	15	100	----	67	100	----
Double Cross 2304	----	----	----	0	0	1	1	8	17	1	19	62	38	100	----	100	----	----

RIPE STAGE, COLLECTED JULY 22 [2]

0 °C.:																		
Marquis 1239	----	----	----	0	0	0	0	3	7	0	6	12	5	12	17	3	13	26
Reward 2204	----	----	----	2	2	8	0	4	16	15	36	43	24	44	53	42	57	68
Kubanka 2310	----	----	----	0	14	35	0	9	75	0	11	56	1	18	61	0	12	81
Double Cross 2304	----	----	----	0	0	2	0	0	2	0	0	1	0	0	0	0	0	4
10 °C.:																		
Marquis 1239	----	----	----	0	0	1	0	0	3	2	9	10	4	12	17	12	23	38
Reward 2204	----	----	----	1	4	12	1	14	24	23	39	44	26	43	50	53	61	79
Kubanka 2310	----	----	----	0	6	17	0	3	50	0	4	27	0	8	42	0	5	84
Double Cross 2304	----	----	----	0	0	0	0	0	0	0	1	2	0	2	3	0	1	13
20 °C.:																		
Marquis 1239	0	0	0	0	2	5	0	2	8	10	22	23	35	50	54	55	64	81
Reward 2204	0	3	4	4	25	27	20	41	54	62	77	84	78	84	86	82	87	92
Kubanka 2310	0	6	20	0	18	40	0	1	34	0	12	61	0	12	43	4	16	74
Double Cross 2304	0	0	0	0	0	0	0	0	3	0	1	1	1	3	4	1	9	40
30 °C.:																		
Marquis 1239	----	----	----	10	22	23	8	22	42	55	95	95	86	100	----	100	----	----
Reward 2204	----	----	----	31	59	63	66	83	96	88	98	98	97	99	99	100	----	----
Kubanka 2310	----	----	----	0	39	56	4	58	97	23	99	100	79	97	98	89	98	----
Double Cross 2304	----	----	----	0	2	2	4	6	9	14	85	92	93	98	98	100	----	----
35 °C.:																		
Marquis 1239	----	----	----	4	15	26	19	43	63	47	94	96	89	100	----	99	99	99
Reward 2204	----	----	----	24	47	53	59	82	90	82	99	99	94	100	----	100	----	----
Kubanka 231C	----	----	----	0	44	73	0	68	98	78	99	99	90	99	100	97	100	----
Double Cross 2304	----	----	----	0	3	3	1	6	30	59	96	96	99	100	----	100	----	----

[1] The first test was made July 13, second test July 20, third test July 28, fourth test Aug. 3, fifth test Aug. 10, and sixth test Aug. 17.

[2] The first test was made July 22, second test July 30, third test Aug. 5, fourth test Aug. 12, fifth test Aug. 19, and sixth test Aug. 26.

THE ESTIMATION OF THE HEAT PRODUCTION OF CATTLE FROM THE INSENSIBLE LOSS IN BODY WEIGHT [1]

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INTRODUCTION

The mere instrumental errors incurred in measuring the heat elimination or the respiratory exchange of farm animals, amounting to 1 or 2 percent or less, are not factors of great moment among the many involved in the errors attached to the final significant calculations. The interpretive errors incurred in estimating heat production from heat elimination or respiratory exchange are possibly greater, although their precise magnitude is impossible to assess in the absence of a direct method of measuring heat production. However, what might be called the biological errors in animal calorimetry are by far the most serious, both because of their magnitude and because of the difficulty involved in their removal. These errors are incurred when successive comparative observations are made upon the same animal, but are probably revealed in their greatest magnitude only when similar observations are made upon a number of animals.

If a steer is put into a respiration chamber for 2 or 3 consecutive days under the same conditions of feeding and management, the daily estimates of heat production will of course not be identical, even when corrections for variable muscular activity, insofar as this is measurable, are applied. The average differences between the results for successive days will be 2 or 3 percent, while in individual cases deviations as high as 5 percent are not uncommon. Throughout the publications of the Institute of Animal Nutrition of Pennsylvania State College individual differences between animals with reference to activity, digestive ability, basal metabolism, and heat increment following feeding are repeatedly cited and discussed. From four recent publications (*8*, *9*, *10*, *11*) [3] the writers have computed an average percentage difference of 7.1 between pairs of determinations on different steers of the net energy value of rations for maintenance, with individual differences as high as 13.9 percent. The earlier work of Armsby (*1*) shows even wider individual differences (up to 24 percent) and other laboratories have reported the same experience. Thus Kleiber (*16*) has calculated a coefficient of variation of 11 percent exhibited by a series of 11 determinations of the net energy value of starch reported by Kellner and Kühn. This coefficient means that the occurrence of deviations of as much as 22 percent between individual and average net energy values is not highly improbable.

[1] Received for publication Nov. 14, 1935; issued July 1936.

[2] The writers take great pleasure in acknowledging the assistance of members of the Animal Nutrition Division in carrying out the exacting experiments reported herein. Particular credit is due W. T. Haines, who assumed much of the responsibility of the care for the animals, the proper condition of the respiration apparatus, and the analyses of the chamber air.

[3] Reference is made by number (italic) to Literature Cited, p. 853.

Thus it appears that the significant technical problems of animal calorimetry relate, not to the diminution of instrumental errors, but more particularly to the diminution of the inherent biological errors or to the reduction of their effect upon the final calculations. The latter plan is the more practicable and the one more likely to justify itself. The effect of the biological errors upon the final average results of calorimetric work (net energy values, maintenance, and production requirements) may be diminished by increasing the number of animals upon which measurements are made. But, for purely practical reasons, any considerable increase in the number of experimental subjects must be accompanied by a decrease in the time, labor, and expense involved in securing individual measurements.

What appears to be a promising method of estimating the heat production of animals in a simple manner rests upon the determination of the so-called "insensible perspiration" or, better, "insensible loss in body weight." This loss in weight is the result of the gaseous exchange between an animal and its environment, and is equal to the difference in weight between the gases emitted from the body (carbon dioxide, water vapor, and methane) and the oxygen taken in. Over short periods the insensible loss in weight may be measured by placing the animal upon a sensitive balance and noting the loss in weight, but this simple method is inapplicable over long periods, since normally sensible accretions (food and water) and excretions (feces and urine) to and from the body will occur. The insensible loss in weight over periods of days or weeks may be obtained by weighing the animal at the beginning and at the end of the desired period, together with all food and water consumed and urine and feces excreted. The insensible loss in weight is then computed from the following equation:

$$I=(B_1+N+W)-(B_2+U+F)$$

in which I is the insensible loss in body weight, B_1 and B_2 the initia and final body weights, respectively, N the food intake, W the intake of water, U the output of urine, and F the fecal excretion. If the insensible loss in body weight may be used successfully in the prediction of heat production, it is evident that a simple gravimetric method has replaced the elaborate and laborious technique of direct and indirect calorimetry.

The relation between the insensible loss in weight and the heat elimination of an animal relates entirely to one factor in this loss, namely, the water vapor. The significance of this factor in the prediction of the total heat elimination resides in the observation, repeatedly recorded in the literature, that the percentage of heat eliminated from an animal in the vaporization of water from the skin and the respiratory tract is remarkably constant, biologically speaking, under more or less restricted conditions. A historical discussion of this literature has been prepared by Benedict and Root (*4*), while discussions of the nature of the insensible loss in weight and of the conditions affecting it have been offered by Benedict and Wardlaw (*5*), Benedict (*2*), and Kuno (*19*).

The relation between the water vaporized from the body and the insensible weight loss is a function of the respiratory quotient and of the percentage of the heat elimination represented in the vaporized water, disregarding for the moment the excretion of methane in ruminants.

It may be shown [4] that the ratio of vaporized water to insensible loss is represented by the following expression:

$$\frac{W}{I}=\frac{ce}{ce+1.1466r-0.8288}$$

[4] The derivation of formulas concerned with the relations existing between the insensible loss in body weight, the water vaporized, and the heat production follows:

1. The ratio of water vaporized to the insensible loss in body weight

Let a = liters of CO_2 produced
b = liters of O_2 consumed
c = fraction of total heat lost as vaporized water
d = latent heat of vaporization per gram of water
e = heat equivalent of a liter of oxygen consumed
$= 4.686+1.23\left(\frac{a}{b}-0.707\right)$
h = heat produced $= be$
w = weight of water vaporized
i = insensible loss in body weight

Then, total heat of vaporization $= bce$

total water vaporized $= w = \frac{bce}{d}$

$$\text{insensible loss} = i = \frac{bce}{d}+1.9769a-1.4290b \tag{1}$$

$$\frac{w}{i}=\frac{\frac{bce}{d}}{\frac{bce}{d}+1.9769a-1.4290b} \tag{2}$$

$$=\frac{ce}{ce+1.9769\frac{a}{b}\cdot d-1.4290d} \tag{3}$$

If $d=0.580$

$$\text{Then } \frac{w}{i}=\frac{ce}{ce+1.1466\frac{a}{b}-0.8288} \tag{4}$$

2. The fraction (c) of total heat lost as vaporized water

From equation (4)

$$ice=wce+1.1466\frac{a}{b}\cdot w-0.8288w \tag{5}$$

$$wce-ice=0.8288w-1.1466\frac{a}{o}\cdot w \tag{6}$$

$$c=\frac{0.8288w-1.1466\frac{a}{b}\cdot w}{we-ie} \tag{7}$$

3. The water vaporized

$$c=\frac{0.580w}{h} \tag{8}$$

Combining (5) and (8)

$$\frac{0.580w^2e}{h}+1.1466\frac{a}{b}\cdot w-0.8288w=\frac{0.580iew}{h} \tag{9}$$

Dividing by w and multiplying by h

$$0.580we+1.1466\frac{a}{b}\cdot h-0.8288h=0.580ie \tag{10}$$

Dividing by 0.580 and transposing

$$we=1.4290h-1.9769\frac{a}{b}\cdot h+ie \tag{11}$$

$$w=\frac{1.4290h-1.9769\frac{a}{b}\cdot h+ie}{e} \tag{12}$$

4. The heat produced

From (8)

$$w=\frac{ch}{0.580} \tag{13}$$

Combining (12) and (13)

$$\frac{che}{0.580}=1.4290h-1.9769\frac{ah}{b}\cdot+ie \tag{14}$$

Simplifying

$$h=\frac{ie}{1.7241ce+1.9769\frac{a}{b}-1.4290} \tag{15}$$

NOTE.—The absolute density of CO_2 is equivalent to 1.9769 g. per liter according to the International Critical Tables (*30, v. 3*). If, as Kleiber (*16, p. 11*) believes, the theoretical value of 1.9652 is preferable to use in this connection, because of the small concentration in which CO_2 occurs in chamber air, the formulas developed above may be readily changed accordingly.

in which c is the fraction of the total heat that is lost as vaporized water, e is the calorie equivalent of a liter of oxygen consumed (and is a function of r for respiratory quotients between 0.7 and 1), and r is the respiratory quotient. For purposes of illustration, the value of $\frac{W}{I}$, expressed as a percentage, is given in table 1 for various values of c and r.

TABLE 1.—*The percentage of the insensible weight loss represented by vaporized water for various values of c and r*

Percentage of heat lost as vaporized water (c×100)	Percentage loss at respiratory quotient (r) of—						
	0.707	0.75	0.80	0.85	0.90	0.95	1.00
20	102.0	96.8	91.6	87.0	82.9	79.3	76.1
25	101.6	97.4	93.1	89.3	85.8	82.7	79.9
30	101.3	97.9	94.2	90.9	87.9	85.2	82.7
35	101.1	98.2	95.0	92.1	89.5	87.0	84.8
40	101.0	98.4	95.6	93.0	90.7	88.4	86.4
45	100.9	98.6	96.1	93.8	91.6	89.6	87.7
50	100.8	98.7	96.4	94.3	92.4	90.5	88.8

For a respiratory quotient of 0.723, the weight of CO_2 emitted and of O_2 consumed are equal, so that at this respiratory quotient the insensible loss measures exactly the vaporized water. At lesser respiratory quotients the insensible loss is less than the weight of vaporized water, while at greater respiratory quotients it is greater, until for a respiratory quotient of 1, the vaporized water accounts for only 76 to 89 percent of the insensible loss as the percentage of heat lost in vaporization varies from 20 to 50. It is evident also that as the latter percentage increases, the weight of vaporized water tends to approach the insensible loss in weight at any respiratory quotient.

Although Benedict and Root (*4*) proposed a method of estimating the basal heat production of adult humans from the insensible loss in body weight, and Levine and others (*22, 23, 24, 25*) proposed a similar method for infants, Newburgh and his associates (*14, 32, 33*) have perfected the method and extended it to the determination of the total heat production for the day and for even longer periods, and have studied the effect of many conditions, in both nude and clothed subjects, on the relationship of insensible water and heat eliminated. Their success in particular inspired the investigations reported in this paper.

Previous studies of the relationship between the insensible loss in body weight and the heat production of cattle have not indicated a correlation sufficiently close to insure an acceptable prediction of the latter from the former. However, both Benedict and Ritzman (*3, p. 75*) and Kriss (*17, 18*) expressed the opinion that a variable environmental temperature may have been a disturbing factor, while Kriss further noted the disturbing effect of a variable hair coat, an observation confirming previous work from the same laboratory (*7*) as well as the results of Lefèvre and Auguet (*21*) on sheep. In the nude human subject Wiley and Newburgh (*33*) noted a steadily increasing percentage of heat lost in vaporization as the environmental temperature increased up to 30° to 31° C., at which point visible perspiration appeared and initiated a marked acceleration in the rate of increase.

In the clothed subject, however, the percentage was not appreciably disturbed within the range of 18° to 30° C. Kayser (*15*) observed in pigeons and rabbits a curvilinear relationship between environmental temperature and the ratio of vaporized water to oxygen consumed, while Lefèvre and Auguet (*21*) showed that in sheep also, whether sheared or unsheared, the percentage of heat lost as latent heat of vaporization increased with the surrounding temperature.

While increasing environmental humidity continuously depresses the evaporation of water from the skin of the nude human subject (*33*), in the clothed human subject a variation in humidity from 20 to 60 percent has no such effect. Also, in ewes carrying a heavy fleece, the evaporation of water is not depressed by increasing the humidity of the surrounding air until values of 80 to 90 percent are attained, according to Lefèvre and Auguet (*20*). On the other hand, extreme dehydration of the body may depress the evaporation of water from the surface (*12*, *26*, *28*, *31*). The effect of the intensity of heat production on the loss of heat in the vaporization of water does not seem to be considerable, if appreciable at all (*13*, *33*). This phase of the subject, however, evidently requires further study.

Undoubtedly these and other disturbing factors are responsible for the occasional erratic values obtained for the ratio of basal insensible perspiration to basal metabolism in humans observed by Magendantz (*27*), as well as for the many other instances of the same nature cited by him from other laboratories.

PLAN OF THE EXPERIMENT

The accuracy of any prediction of the heat production of an animal from its insensible loss in body weight rests upon the constancy of the proportion of the total heat emitted as vaporized water. It seems evident from previous work that this proportion varies with environmental conditions, particularly with environmental temperature, and that animals other than the clothed human subject are particularly subject to these environmental changes.

The steers serving as subjects of these experiments were, therefore, confined in an air-conditioned and insulated room, in which temperature could be maintained constant within 2° or 3° F. and relative humidity within 5 or 6 percent. The urine and feces were collected beneath the floor of the room in such a way as to minimize the evaporation of water. The steers were weighed daily on scales accurate to 0.25 pound, situated immediately outside of the stall room door. The day's urine and feces were weighed, for each steer, at the exact time the body weight was taken. The time spent by each steer in the standing position was measured by an electric clock, the current to which was shut off by an arrangement of chains and pulleys as long as the steer remained in the recumbent position.

Water was offered the steers daily after securing their body weights, and the amount consumed was determined by immediately reweighing. The steers were fed twice daily. In most of the experiments reported below, both feed and water were brought to the temperature of the air-conditioned room before they were consumed.

The ration fed, which was varied in different experimental periods, consisted of varying proportions of corn and chopped alfalfa hay with small additions of salt (28 or 56 g daily). In periods in which small

proportions of alfalfa were fed, small amounts of bonemeal and cod-liver oil were also given, while in the later periods, when it was desired to increase feed consumption to the limit of capacity, brown sugar was fed at the rate of 100 g per meal. However, this attempt to increase the palatability of the ration was not accompanied by any appreciable measure of success.

The plan of the experiment was to determine the insensible loss in body weight of each steer in a period on constant feed, lasting 14 days or longer, and to measure also the heat production and gaseous exchange of the steer on the same level of feed, generally during a 72-hour confinement in the respiration chamber previously described (*29*). The latter determination was made at a time (either before or after) as close to the former as was feasible with the equipment available. During the former period (or for at least 2 weeks of it) the urine and feces of the steer were quantitatively collected, and samples of them, as well as of the feed, were analyzed for nitrogen and their heats of combustion were determined in the bomb calorimeter. Two such comparative determinations between insensible loss in body weight and heat production were made upon three of the four steers, and three determinations upon the other.

In the preliminary experiments, involving maintenance levels of feeding, the methane production was not determined and no account of it was taken in the computations of heat production or in the interpretation of the insensible loss in weight. However, in the main experiments the methane content of the outgoing air was determined gasometrically, and the methane production was considered in all the computations of indirect calorimetry, as previously described (*29*), and in the interpretation of the insensible loss in body weight.

RESULTS OF THE EXPERIMENT

In preliminary experiments, extending over 2 years, an investigation was made of the factors affecting the insensible loss in body weight, since these would be the factors that must be controlled in all later work. The first factor investigated was the environmental temperature. The results are briefly summarized in table 2. The heat-production values in column 12 of the table are derived from an average for each steer of either three or four respiration tests, each of which extended over 48 hours. These tests were all made at chamber temperatures of 75° F. or above. Small corrections were applied to these averages for differences in body weight and times spent in the standing position for the several periods. The average heat productions, expressed to a standard day of 12 hours standing were: Steer 1, 9,744 calories for a body weight of 474 kg; steer 2, 9,943 calories for a weight of 480 kg; steer 3, 7,871 calories for a weight of 331 kg; steer 4, 7,936 calories for a weight of 346 kg. The corrections applied to these figures for body weight were made on the basis of a basal metabolic rate (the steer being in the lying position) of 1,581 calories per square meter of body surface, the surface area being computed by Brody's formula (*6*) for beef cattle, $S_{m^2}=0.13\ W^{0.56}$ kg. The corrections for position (standing and lying) were made on the basis of an increment of 62 calories per 500 kg per hour for the standing position (*29*). Throughout these tests the steers were subsisting on an approximate maintenance ration consisting of equal parts of corn and alfalfa hay.

The weight of water vaporized was computed from equation (12) of footnote 4, p. 839. The respiratory quotients were very close to 1 in all cases, being 1.000 for steer 1, 0.988 for steer 2, and 0.995 for steers 3 and 4.

TABLE 2.—*The effect of room temperature on the insensible loss in weight and the vaporization of water from the body*

Steer no.	Room temperature	Humidity	Average body weight	Feed eaten daily	Water drunk daily	Daily urine	Daily feces	Daily insensible loss in weight	Water vaporized		Heat produced daily	Heat of vaporization	
									Per day	As ratio of insensible loss		Total	As ratio of total heat
	° F.	*Percent*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Percent*	*Calories*	*Calories*	*Percent*
1	69	51	469	4	16.07	8.10	3.75	8.20	7.119	86.8	9,954	4,129	41.5
	58	64	481	4	12.16	7.17	3.51	4.97	3.900	78.5	9,862	2,262	22.9
	52	76	473	4	11.43	6.70	3.64	4.45	3.384	76.0	9,815	1,963	20.0
	43	88	474	4	14.82	8.67	4.13	4.61	3.575	77.5	9,538	2,073	21.7
2	69	51	480	4	10.30	2.35	3.54	7.57	6.559	86.6	9,701	3,804	39.2
	58	64	488	4	5.31	2.26	3.22	4.54	3.522	77.6	9,776	2,043	20.9
	52	76	479	4	5.37	2.27	3.26	3.93	2.918	74.2	9,713	1,692	17.4
	43	88	474	4	7.92	3.61	3.69	3.49	2.480	71.1	9,666	1,438	14.8
3	69	51	332	3	9.97	3.78	2.55	6.03	5.191	86.1	7,855	3,011	38.3
	58	64	340	3	8.42	5.46	2.39	4.00	3.154	78.9	7,928	1,829	23.1
	52	76	330	3	7.35	3.51	2.55	3.61	2.770	76.7	7,865	1,607	20.4
	43	88	322	3	10.39	6.64	2.88	3.00	2.167	72.2	7,802	1,257	16.1
4	69	51	342	3	9.04	1.96	3.12	6.59	5.760	87.4	7,778	3,341	42.9
	58	64	355	3	8.15	3.81	2.50	4.14	3.298	79.7	7,885	1,913	24.3
	52	76	348	3	5.82	2.36	2.72	3.69	2.838	76.9	7,838	1,646	21.0
	43	88	340	3	6.95	2.68	3.21	3.38	2.553	75.5	7,747	1,481	19.1

It will be noted that the insensible losses in body weight (table 2, column 9), the vaporized water, both the absolute values and the percentages on the insensible losses in weight, and the percentages of heat lost in the vaporization of water, decreased with one exception (steer 1, from periods 3 to 4) as the room temperature decreased. The averages of the latter percentages for all four steers were, in the order of decreasing temperatures, 40.5, 22.8, 19.7, and 17.9. It is quite possible that at the lowest temperature, 43° F., the steers were below their critical temperatures, in which case the calculated percentages would be too low, since the heat productions would be higher than those assumed on the basis of determinations made at higher temperatures in the respiration chamber.

In the experiments just reviewed, no particular attention was paid to the control of the humidity of the room air, the humidities actually obtained rising with decreasing temperatures because of the increasing difficulty of dehumidifying the air. With the temperature maintained at 68° to 70° F., tests were made of the effect upon the insensible loss in body weight of varying the humidity of the air. The same steers were used and they were maintained upon the same rations. The comparisons given in table 3 relate to short periods immediately preceding and immediately following a marked change in relative humidity.

Unfortunately the results of this test are indecisive. A comparison of periods 1 and 2, differing the most in relative humidity, would support the conclusion that a drop from 80 to 47 percent exerted no

effect on the vaporization of water from the bodies of the steers, three of the steers, in fact, showing a decrease in insensible loss rather than the expected increase if any effect at all were produced. On the other hand, in periods 3 and 4, an increase in relative humidity from 59 to 78 percent was associated in all steers with a more or less considerable drop in the insensible loss in body weight, and presumably in the vaporization of water. It is perhaps fair to conclude that if the vaporization of water from the bodies of these steers is inversely correlated with relative humidity between the limits of 47 and 80 percent, the effect is so slight that it may be obscured (or greatly accentuated) by uncontrolled factors.

TABLE 3.—*The effect of relative humidity on the insensible loss in body weight of steers at chamber temperatures of 68° to 70° F.*

Steer no.	Period		Relative humidity	Insensible loss in weight	Steer no.	Period		Relative humidity	Insensible loss in weight
	No.	*Days*	*Percent*	*Kilograms*		*No.*	*Days*	*Percent*	*Kilograms*
1	1	13	80	6.40	3	1	10	80	3.74
	2	8	47	6.65		2	4	47	3.25
	3	6	59	5.59		3	9	59	2.97
	4	8	78	5.39		4	10	78	2.80
2	1	5	80	6.04	4	1	6	80	4.62
	2	9	47	5.73		2	10	47	4.51
	3	7	59	4.81		3	7	59	3.73
	4	10	78	4.47		4	8	78	3.14

As these preliminary tests progressed it was evident that another factor (or other factors) than the temperature and humidity of the surrounding air was modifying the vaporization of water from the steers and hence the insensible loss in body weight. This uncontrolled factor (or factors) was evident only over a considerable period, exerting a progressive effect, but not disturbing the day-to-day variation. The data of table 3 reveal the type of effect under discussion: In periods 3 and 4, the insensible losses of all steers were lower than in periods 1 and 2, although the ration was the same and the body weights were nearly so.

The observations of the Institute of Animal Nutrition at Pennsylvania State College (*7*, *17*, *18*) on the effect of shearing on the insensible loss in body weight of steers, as well as those of Lefèvre and Auguet (*21*) on the effect of shearing sheep on the vaporization of water, suggested a solution of this problem. Accordingly, the effect of shearing on four young steer calves was studied, with the results summarized in table 4. The experimental periods immediately preceded or followed shearing and were 14 days in length except the final period (after shearing), which was only 8 days in length. In comparable periods, all conditions were kept the same except the hair coat of the steers.

TABLE 4.—*The effect of shearing on the daily insensible loss in body weight of steers and on certain features of their behavior, when fed 2 different rations*

Steer no.	Condition	Average body weight	Daily gain in weight	Water consumed daily	Time spent standing per day	Pulse rate	Daily insensible loss in body weight
		Kilograms	*Kilograms*	*Kilograms*	*Hours*		*Kilograms*
DAILY RATION: 2.4 KG OF CORN PLUS 3.4 KG OF CUT ALFALFA HAY							
1	Before shearing	258	+0.34	10.36	9.32	64.6	6.59
	After shearing	270	+.94	9.30	8.91	60.8	5.08
2	Before shearing	257	+.66	10.30	10.09	67.3	5.50
	After shearing	268	+.55	9.67	11.71	60.1	5.21
3	Before shearing	243	+.21	10.71	5.26	50.3	5.60
	After shearing	254	+1.04	9.81	5.61	52.2	4.56
4	Before shearing						
	After shearing	238	+.73	10.57	6.94	59.6	5.52
DAILY RATION: 3.6 KG OF CORN PLUS 1.2 KG OF CUT ALFALFA HAY							
1	Before shearing	317	+.65	9.58	11.77	66.7	7.36
	After shearing	327	+.71	7.45	8.10	61.9	5.29
2	Before shearing	300	+.26	9.40	11.15	64.4	6.83
	After shearing	304	+.93	8.58	9.75	60.5	5.27
3	Before shearing	297	+.23	8.85	8.87	56.4	6.00
	After shearing	305	+.37	7.90	7.10	54.3	5.24
4	Before shearing	289	−.10	8.94	8.10	63.0	7.74
	After shearing	296	+.91	7.40	7.46	60.5	5.44

It is evident that shearing decreased the insensible loss in body weight, the observed decreases ranging from 5.3 to 29.7 percent and averaging 19.8 percent. This decrease may have been the result of two factors (1) a decrease in skin temperature following removal of the insulating hair, (2) a decrease in restlessness of the animal due to a removal of scurf and dirt from the skin. The advantage of periodically removing scurf and dirt from the skin of steers on a long-time experiment is obvious, but this factor was not an important one in this case, since in another test currying alone failed to exert an appreciable effect on the insensible loss in body weight. Hence, the decrease in skin temperature must have been the effective factor in shearing.

The decrease in skin temperature occasioned a decreased loss of water by evaporation from the skin for each calorie of heat dissipated. As a result, less water was consumed daily in all cases after shearing than before; but this reduction in water intake was generally less than the reduction in water vaporized from the body. The daily volume of urine excreted (not shown in the table) was also generally less after shearing than before; hence shearing must have induced a hydration of the bodies of the steers, an effect that extended over many days. This storage of water probably accounts for the greater gain in body weight after shearing than before in all cases but one (the steer showing the least effect of shearing), and this greater gain after shearing would continue until the appetite for water adjusts itself to the decreased demand.

The advantages of frequent shearing in determining insensible losses in body weight representative of a given steer, ration, and set of environmental conditions are marked, and their presence is clearly evident from the data of table 4 in the much greater uniformity of

the insensible loss values obtained after shearing as compared with those obtained before. Thus, in the second comparison in the table the standard deviation of the insensible losses before shearing was 0.65 kg and the coefficient of variation 9.3. The same statistics after shearing were 0.076 kg and 1.4.

In securing constant and representative values for the insensible loss in body weight of steers, a fairly constant intake of water was found desirable. Abstention from water for several days will cause a dehydration of the body, irregular and abnormally low vaporization of water, and unrepresentative insensible losses in body weight. One steer had to be removed from the preliminary experiments because of a very irregular water appetite.

The principal experiments, concerned with the possibility of predicting the heat production of steers from their contemporaneous insensible loss in body weight, were performed in the following year upon the same four steers used in the last preliminary test (table 4). The tests were carried out with the observance of all the precautions indicated by the preliminary studies. The room temperature was kept constant at 76° F. and the relative humidity at 52 to 54 percent. The steers were sheared before each determination of the insensible loss in body weight. The control of air conditions in the respiration chamber was not feasible, but the temperature was allowed to vary only between 74° and 81° or 82°. The humidity, under no control whatever, averaged 78 to 80 percent. It is not believed that these chamber conditions either depressed or accelerated appreciably the metabolic rate obtaining during the determination of the corresponding insensible loss in body weight.

The rations used have already been described. Their content of metabolizable energy was determined in two tests upon each of the four steers, with the results given in table 5. The corn contained an average of 1.62 percent of nitrogen and 3.91 calories of gross energy per gram; the alfalfa hay, 2.45 percent of nitrogen and 4.04 calories of gross energy per gram; for the brown sugar, these values were 0.055 percent of nitrogen and 3.65 calories per gram. It is worthy of note that steers 1 and 4 were distinctly better utilizers of feed energy than were steers 2 and 3. Steer 3 was almost continuously bloated throughout these experiments.

TABLE 5.—*The metabolizable energy content of the experimental rations*

Steer no.	Daily ration			Gross energy in—				Metabolizable energy		
	Corn	Alfalfa hay	Sugar	Daily feed	Daily feces	Daily urine	Daily methane	Total per day	Per kilogram of feed	Percentage of gross energy
	Kilograms	*Kilograms*	*Kilograms*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*	*Calories*
1	3.84	0.96	0.0	18,804	3,587	470	1,174	13,573	2,828	72.2
	4.56	2.28	.2	27,881	7,328	514	2,214	17,825	2,606	63.9
2	3.40	1.70	0	20,274	6,334	392	1,161	12,387	2,401	61.1
	3.92	1.95	.2	23,969	8,674	479	1,521	13,295	2,193	55.5
3	3.84	.96	0	18,804	5,252	376	1,321	11,875	2,474	63.2
	3.40	1.70	.2	20,887	7,236	462	1,961	11,228	2,202	53.8
4	3.84	.96	0	18,804	3,537	423	1,801	13,043	2,717	69.4
	3.40	1.70	.2	20,887	5,860	475	1,500	13,052	2,559	62.5

The insensible losses in body weight of the steers, together with the data upon which the computation of these losses is based, are summarized in table 6. The only feature of these results requiring comment here is the variability of the day-to-day insensible losses in these various experimental periods. The pertinent standard deviations and coefficients of variation are given in the last two columns of the table. The coefficients of variation range from 3.43 to 8.84, and average 6.20, a satisfactorily low figure. The day-to-day variations in these experiments may be compared with the only record of its kind found in the literature, a 38-day record of a human subject reported by Johnston and Newburgh (*14*). The subject, a normal man 32 years old, spent practically all of his time in bed, his activity being rigidly restricted. The temperature of the room was kept close to 72° F. during the day. Considering only the last 30 days during which the intake of food was constant, the average daily insensible loss was 976, the standard deviation was 69.5, and the coefficient of variation was 8.71. In later work, Newburgh, Wiley, and Lashmet (*32*) report daily estimations of the insensible (vaporized) water for seven subjects, pursuing their usual routine duties, but subsisting upon a constant diet approximating closely their maintenance requirements. Ruling out the values obtained on extra cold days and days on which unusual work was done, the coefficients of variation for 15 periods of 6 to 15 days each ranged from 3.21 to 13, and averaged 8.4.

TABLE 6.—*The insensible loss in body weight of the steers per day and data upon which computations were based*

Steer no.	Period no.	Length of period	Average body weight	Average daily gain in weight	Time in standing position	Feed consumed	Water drunk	Urine	Feces	Insensible loss in body weight	Variability of daily insensible losses	
											Standard deviation	Coefficient of variation
		Days	*Kilograms*	*Kilograms*	*Hours*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	*Kilograms*	
1	1	22	414	+0.35	6.14	4.85	7.25	3.11	2.41	6.23	0.436	6.99
	2	28	481	+.71	6.57	7.11	13.51	5.23	5.45	9.23	.691	7.49
2	1	14	379	+.29	10.67	5.13	9.10	3.89	4.18	5.87	.248	4.22
	2	21	396	+.26	11.12	6.18	10.65	4.31	5.48	6.78	.297	4.38
3	1	24	377	+.33	7.66	4.85	9.46	4.88	3.44	5.66	.436	7.70
	2	21	421	+.69	7.65	5.36	11.13	5.09	4.61	6.10	.539	8.84
4	1	30	393	+.25	7.03	4.85	8.32	3.33	2.56	7.03	.509	7.24
	2	16	426	+.68	7.34	5.33	12.55	5.17	4.27	7.76	.266	3.43
	3	14	431	+.21	7.27	5.36	11.72	5.49	4.08	7.30	.404	5.53

The coefficients of variation given in table 6 are considerably lower and more uniform than those calculated from the results of the preliminary investigations. For example, in the tests summarized in table 2, the coefficients of variation of the daily insensible losses in weight ranged from 2.91 to 12.56, averaging 7.06.

The results of the respiration experiments on the four steers are summarized in table 7. The first three experiments lasted for 48 hours, but all others extended through 72 hours. The successive 24-hour values are all recorded in the table. The average heat productions are ordinarily the average of the corresponding 2- or 3-day

values, although in three instances, one of the three daily values was omitted from the average because it was considerably higher than the other two, probably because of exceptionally greater activity. In one of the cases (steer 2, experiment 118–35) objective evidence of exceptional activity was obtained.

TABLE 7.—*The respiratory exchange and heat production of steers per day and data upon which computations were based* [1]

Steer no.	Experiment no.	Average body weight	Day of test	Daily feed: Corn	Daily feed: Alfalfa	Daily feed: Sugar	Time in standing position	Oxygen consumed	Carbon dioxide produced	Methane produced	Respiratory quotient	Heat production
		Kilograms		*Kilograms*	*Kilograms*	*Kilograms*	*Hours*	*Liters*	*Liters*	*Kilograms*		*Calories*
1	116–35	430	First	3.84	0.96	0.0	7.75	1,809	1,814	0.087	1.003	9,051
			Second	3.84	.96	0	8.38	1,783	1,881	.090	1.055	9,029
			Average	3.84	.96	0	8.06	1,796	1,847	.088	1.028	9,040
	119–35	481	First	4.60	2.30	.2	8.96	2,452	2,720	.169	1.109	12,338
			Second	4.60	2.30	.2	7.70	2,438	2,676	.168	1.098	12,438
			Third	4.60	2.30	.2	.....	2,461	2,666	.161	1.083	12,521
			Average	4.60	2.30	.2	8.33	2,450	2,687	.166	1.097	12,499
2	118–35	366	First	3.40	1.70	0	6.04	1,705	1,818	.086	1.066	8,659
			Second	3.40	1.70	0	6.96	1,683	1,865	.088	1.108	8,625
			Third	3.40	1.70	0	(13.06)	(1,884)	(1,971)	(.093)	(1.046)	(9,527)
			Average[2]	3.40	1.70	0	6.50	1,694	1,842	.087	1.087	8,642
	122–35	397	First	4.00	2.00	.2	10.10	1,834	2,028	.097	1.106	9,394
			Second	4.00	2.00	.2	11.36	1,953	2,199	.126	1.126	10,032
			Third	4.00	2.00	.2	11.49	2,132	2,318	.120	1.087	10,871
			Average[3]	4.00	2.00	.2	10.98	1,973	2,182	.114	1.106	10,099
3	115–35	382	First	3.84	.96	0	9.23	1,866	1,927	.096	1.033	9,402
			Second	3.84	.96	0	10.42	2,015	2,037	.102	1.011	10,099
			Average	3.84	.96	0	9.82	1,940	1,982	.099	1.022	9,750
	121–35	415	First	3.40	1.70	.2	9.18	2,061	2,126	.146	1.032	10,344
			Second	3.40	1.70	.2	6.93	2,005	2,110	.134	1.052	10,122
			Third	3.40	1.70	.2	6.86	1,968	2,039	.162	1.036	9,868
			Average[4]	3.40	1.70	.2	7.66	2,011	2,092	.147	1.040	10,111
4	117–35	406	First	3.84	.96	0	9.73	2,040	2,228	.134	1.092	10,400
			Second	3.84	.96	0	8.84	1,996	2,262	.136	1.133	10,265
			Average	3.84	.96	0	9.28	2,018	2,245	.135	1.112	10,332
	120–35	426	First	3.40	1.70	.2	6.55	2,132	2,316	.119	1.086	10,874
			Second	3.40	1.70	.2	12.76	2,175	2,302	.107	1.058	11,031
			Third	3.40	1.70	.2	(10.96)	(2,636)	(2,597)	(.106)	(.985)	(13,152)
			Average	3.40	1.70	.2	11.29	2,154	2,309	.113	1.072	10,952
	123–35	441	First	3.40	1.70	.2	8.88	2,054	2,162	.109	1.053	10,394
			Second	3.40	1.70	.2	9.33	2,070	2,244	.114	1.084	10,552
			Third	3.40	1.70	.2	(9.63)	(2,287)	(2,356)	(.119)	(1.030)	(11,517)
			Average	3.40	1.70	.2	9.11	2,062	2,203	.112	1.068	10,473

[1] The values enclosed in parentheses are not included in the respective averages.
[2] There were orts in this 3-day test amounting to 630 g., dry weight.
[3] There were orts in this 3-day test amounting to 360 g., dry weight.
[4] Orts weighing 70 g., dry weight.

In table 8, the data of tables 6 and 7 have been utilized in estimating the weight of water vaporized from the steers daily. In combining the two sets of data, the observed heat productions have been corrected to the average body weights and standing records of the periods serving for the determination of the insensible losses in weight, by a method described on page 842. These corrections were all relatively small, ranging from +7 to +324 calories daily. The

weights of respiratory gases (but not of methane) have been similarly corrected, increasing or decreasing the observed values in the same proportions that the corresponding observed heat productions were increased or decreased. While a theoretically better (but much more complicated) method might have been used in making these corrections, the end results would have been very nearly the same.

TABLE 8.—*Computation of percentage of heat lost as vaporized water, the results being expressed on the daily basis*

Steer no.	Period no.	Insensible loss in body weight	Results of respiration experiment [1]					Vaporized water	Latent heat of vaporization	Heat lost as vaporized water
			Experiment no.	Carbon dioxide produced	Methane produced	Oxygen consumed	Heat produced			
		Kilograms		*Kilograms*	*Kilograms*	*Kilograms*	*Calories*	*Kilograms*	*Calories*	*Percent*
1	1	6.23	116–35	3.55	0.09	2.50	8,795	5.09	2,952	33.6
	2	9.23	119–35	5.27	.17	3.47	12,391	7.26	4,211	34.0
2	1	5.87	118–35	3.78	.09	2.51	8,966	4.51	2,616	29.2
	2	6.78	122–35	4.31	.11	2.82	10,106	5.18	3,004	29.7
3	1	5.66	115–35	3.85	.10	2.73	9,593	4.44	2,575	26.8
	2	6.10	121–35	4.16	.15	2.89	10,163	4.68	2,714	26.7
4	1	7.03	117–35	4.34	.13	2.82	10,093	5.38	3,120	30.9
	2	7.76	120–35	4.48	.11	3.02	10,736	6.19	3,590	33.4
	3	7.30	123–35	4.28	.11	2.89	10,281	5.80	3,364	32.7

[1] Except for methane, these values, as compared with those in table 6, are corrected for differences in body weight and in time spent in the standing position between the respiration tests and the periods of insensible loss determination (p. 842).

The vaporized water was computed by subtracting from the insensible loss in body weight the weights of carbon dioxide and of methane excreted, and adding to the remainder the weight of oxygen absorbed. Multiplying the weight of vaporized water by 0.58 gives the heat of vaporization. Expressing the heat of vaporization in each case as a percentage of the total heat produced (and within a small error the total heat eliminated) results in the values recorded in the last column of table 8. These percentages are the most significant results of the experiment.

The percentages of heat output represented by the vaporized water are not constant among the different steers, but for three of the steers duplicate determinations of the percentage are remarkably constant, i. e., 33.6 and 34 for steer 1, 29.2 and 29.7 for steer 2, and 26.8 and 26.7 for steer 3. For steer 4, two of the triplicate determinations are in excellent agreement, 33.4 and 32.7, although the third determination was appreciably smaller, i. e., 30.9. Considering the fact that the duplicate insensible loss determinations, except for the last two on steer 4, were made at intervals ranging from 2 weeks to 3 months, while the intervals between respiration tests for the same steer were nearly the same or longer, this evidence of individuality seems decisive.

It is interesting to note that the steers exhibiting the highest percentages of heat emitted by the vaporization of water, steers 1 and 4, are the steers that metabolized the greater proportions of the gross energy of the feed (table 5) due to a more efficient digestion of the feed. Also, the steer emitting the smallest portion of heat in

vaporized water was almost continuously bloated and excreted greater than average amounts of methane. Whether these relations possess a causal significance cannot at present be determined.

Evidently the best prediction of the heat production of steers from the insensible loss in body weight cannot be made from any average relationship between the two, but should be based upon a relationship determined in preliminary experiments upon each individual steer. With this fact in mind, different methods of making this prediction may now be considered.

The heat production may be very accurately predicted from equation (15) of footnote 4

$$h=\frac{ei}{1.7241ce+1.9769\text{ (r. q.)}-1.4290}$$

but this prediction would require for each steer a knowledge, not only of c, the percentage of heat lost by the evaporation of water, and of i, the insensible loss in body weight, but also of the respiratory quotient and of e, the heat equivalent of a liter of oxygen. If the respiratory quotient is less than 1, e may be computed from it, but if the respiratory quotient is above 1, as it will be on production rations, no rational method for the computation of e is at hand.

If the respiratory quotient for a given steer, the ration, and the level of feeding are known and if the respiratory quotient is above 1, the heat value of a liter of oxygen may be roughly estimated from the respiratory quotient by the following linear equation, describing the relationship observed between the two values in the series of respiration experiments reported in table 7:

$$e=1.242\text{ (r. q.)}+3.744$$

The methane production may be computed with sufficient accuracy from the estimated digestible carbohydrates consumed by using the factor of Armsby (*1*) of 4.5 g of CH_4 per 100 g of digestible carbohydrates. In the predictions to be made below it has been estimated at 21.7 g per kilogram of ration, the average output observed in these experiments.

The first prediction method involves, therefore, the observed insensible loss in body weight (i), the observed percentage of heat lost as vaporized water (c), the observed respiratory quotient, and the estimated value of e, the heat value of a liter of oxygen. In columns 4 and 5 of table 9, the value of this method is assessed by predicting the heat productions of the steers in the various experimental periods as described, and noting the percentage error incurred as computed from the observed heat productions. The average error is only 1.15 and the individual errors do not exceed 3.02 percent, incurred in the first experimental period on steer 4. For this steer, the average value of c for all three periods was used.

TABLE 9.—*Estimation of heat production from insensible loss in body weight by various methods explained in the text*

Steer no.	Experiment no.	Observed heat production [1]	Estimations of heat production							
			Method 1		Method 2		Method 3		Method 4	
			Heat production	Deviation from observed	Heat production	Deviation from observed	Heat production	Deviation from observed	Heat production	Deviation from observed
		Calories	*Calories*	*Percent*	*Calories*	*Percent*	*Calories*	*Percent*	*Calories*	*Percent*
1	116–35	8,795	8,707	−1.00	8,715	−0.91	8,523	−3.09	8,853	+0.66
	119–35	12,391	12,479	+.71	12,450	+.48	12,646	+2.06	13,135	+6.00
2	118–35	8,966	8,874	−1.03	8,857	−1.22	8,957	−.10	9,346	+4.24
	122–35	10,106	10,141	+.35	10,109	+.03	10,341	+2.33	10,791	+6.78
3	115–35	9,593	9,583	−.10	9,596	+.03	9,305	−3.00	9,741	+1.54
	121–35	10,163	10,210	+.46	10,215	+.51	10,026	−1.35	10,496	+3.28
4	117–35	10,093	9,788	−3.02	9,756	−3.34	9,997	−.95	10,399	+3.03
	120–35	10,736	11,027	+2.71	11,014	+2.59	11,038	+2.81	11,481	+6.94
	123–35	10,281	10,384	+1.00	10,374	+.90	10,373	+.90	10,790	+4.95
Average [2]				1.15		1.11		1.84		4.16

[1] Corrected as in table 8.
[2] Disregarding signs of deviations.

A second prediction method would involve arbitrarily assigning a value of 5.047 calories to e, corresponding, at least in animals promoting no considerable gastrointestinal fermentations, to a respiratory quotient of 1. The other bases of prediction remain the same. From table 9 it appears that no loss in accuracy is incurred by assigning an arbitrary, though not unreasonable, value to e. In fact, since e occurs in both the denominator and the numerator of the prediction equation, it may be expected that even considerable errors in the value assigned to it would not lead to serious errors in the estimate of heat production.

In the third prediction method to be considered the average respiratory quotient observed for all steers, i. e., 1.070, will be used in place of the individually observed respiratory quotients, and e will be assigned a value of 5.073, estimated from this respiratory quotient by the equation given above. While the prediction errors are somewhat larger for this method than for the other two, averaging 1.84 percent as compared with 1.15 and 1.11 percent, the method still is satisfactory, since the individual errors do not exceed 3.09 percent.

However, if the respiratory quotient is arbitrarily assigned a value of 1, and the heat value of a liter of oxygen (e) the corresponding value of 5.047 calories, the predictions become appreciably less accurate, the average percentage deviation from the observed heat productions being 4.16. The individual errors range up to 6.94 percent (table 9).

It is clear that the success of a method of predicting the heat production of steers from the insensible loss in body weight depends upon (1) a careful determination of the insensible loss under standardized conditions, (2) a preliminary estimate on each steer of the fraction of heat lost in the vaporization of water, any ration being suitable for this purpose, and (3) fairly good estimates of the respiratory quotients to be expected for the experimental rations. If the errors of

the latter estimates are not more than 0.05 or 0.06, excellent predictions may be expected, while even errors of 0.10 would not be expected to produce errors of estimate greater than 7 percent or so.

SUMMARY AND CONCLUSIONS

The percentage of the insensible loss in body weight represented by vaporized water varies inversely with the respiratory quotient and approaches 100 as the percentage of heat lost from the body by the vaporization of water increases.

The insensible loss in body weight of steers is sensitive to changes in environmental temperature, particularly above a temperature of 70° F. Changes in relative humidity of the surrounding air are without certain effect up to values of 80 percent or more.

The hair coat of a steer is a potent factor in determining the insensible loss in body weight through its effect upon the vaporization of water from the skin. Removal of most of the hair coat by shearing may lower the insensible loss of weight by 20 to 30 percent. The shearing of steers tends markedly to equalize the percentages of heat lost through the vaporization of water.

A regular intake of water favors a regular insensible loss in weight. Abstention from water for several days may depress the insensible loss in weight to abnormally low levels.

With rigorous control of all conditions with reference to the environment and to the animal that are known to affect the vaporization of water, the day-to-day variation in the insensible loss of body weight of steers confined in stalls may be reduced to a magnitude represented by a coefficient of variation of about 6 percent.

The ratio between heat lost by the vaporization of water and total heat output is not constant under the same environmental conditions but is an individual characteristic, at least for steers in the sheared condition.

The heat production of steers on a series of experimental rations may be estimated with small error from the following data:

(1) A careful determination of the insensible loss in body weight on each ration over a period of 2 weeks (or possibly less) under standardized conditions, as defined above.

(2) A preliminary estimate on each steer of the fraction of heat lost in the vaporization of water under the same conditions to be used in the subsequent experiments, any ration being suitable for this purpose.

(3) Fairly good estimates of the respiratory quotients to be expected on the various experimental rations. If the errors in these estimated quotients are not more than 0.05 or 0.06, excellent predictions of heat production may be expected, while even errors as great as 0.1 may not produce errors in estimated heat production of more than 7 percent.

LITERATURE CITED

(1) Armsby, H. P., and Fries, J. A.
1915. NET ENERGY VALUES OF FEEDING STUFFS FOR CATTLE. Jour. Agr. Research 3: 435–491, illus.

(2) Benedict, F. G.
1933. DIE MESSUNG DES UNMERKLICHEN GEWICHTSVERLUSTES BEIM MENSCHEN IN LABORATORIUM UND KLINIK. Ztschr. Gesam Expt. Med. 91: [340]–361, illus.

(3) ——— and Ritzman, E. G.
1927. THE METABOLISM OF THE FASTING STEER. 246 pp., illus. Washington, D. C. (Carnegie Inst. Wash. Pub. 377.)

(4) ——— and Root, H. F.
1926. INSENSIBLE PERSPIRATION: ITS RELATION TO HUMAN PHYSIOLOGY AND PATHOLOGY. Arch. Int. Med. 38: 1–35, illus.

(5) ——— and Wardlaw, H. S. H.
1932. SOME FACTORS DETERMINING THE INSENSIBLE PERSPIRATION OF MAN. Arch. Int. Med. 49: [1010]–1031.

(6) Brody, S., Comfort, J. E., and Matthews, J. S.
1928. GROWTH AND DEVELOPMENT WITH SPECIAL REFERENCE TO DOMESTIC ANIMALS.—XI. FURTHER INVESTIGATIONS ON SURFACE AREA, WITH SPECIAL REFERENCE TO ITS SIGNIFICANCE IN ENERGY METABOLISM. Mo. Agr. Expt. Sta. Research Bull. 115, 60 pp., illus.

(7) Forbes, E. B., Braman, W. W., and Kriss, M., with the cooperation of others.
1926. THE INFLUENCE OF THE ENVIRONMENTAL TEMPERATURE ON THE HEAT PRODUCTION OF CATTLE. Jour. Agr. Research 33: 579–589.

(8) ——— Braman, W. W., and Kriss, M., with the cooperation of others.
1927. NET-ENERGY VALUES OF CORN SILAGE, SOY-BEAN HAY, ALFALFA HAY, AND OATS. Jour. Agr. Research 34: 785–796.

(9) ——— Braman, W. W. and Kriss, M., with the collaboration of others.
1928. THE ENERGY METABOLISM OF CATTLE IN RELATION TO THE PLANE OF NUTRITION. Jour. Agr. Research 37: 253–300, illus.

(10) ——— Braman, W. W., and Kriss, M., with the collaboration of others.
1930. FURTHER STUDIES OF THE ENERGY METABOLISM OF CATTLE IN RELATION TO THE PLANE OF NUTRITION. Jour. Agr. Research 40: 37–78, illus.

(11) ——— Braman, W. W., Kriss, M., and Swift, R. W., with the collaboration of others.
1933. THE ASSOCIATIVE EFFECTS OF FEEDS IN RELATION TO THE UTILIZATION OF FEED ENERGY. Jour. Agr. Research 46: 753–770.

(12) Gilman, A., and Barbour, H. G.
1933. THE RELATION BETWEEN BLOOD OSMOTIC PRESSURE AND INSENSIBLE WEIGHT LOSS. Amer. Jour. Physiol. 104: 392–393, illus.

(13) Hovland, C. I.
1935. HOURLY VARIATIONS IN WEIGHT LOSS FOLLOWING INGESTION OF FOOD. Amer. Jour. Physiol. 111: 448–451.

(14) Johnston, M. W., and Newburgh, L. H.
1930. THE DETERMINATION OF THE TOTAL HEAT ELIMINATED BY THE HUMAN BEING. Jour. Clin. Invest. 8: 147–160, illus.

(15) Kayser, C.
1930. CONTRIBUTION À L'ÉTUDE DE LA RÉGULATION THERMIQUE. L'ÉMISSION D'EAU ET LA RAPPORT $H_2O:O_2$ CHEZ QUELQUE ESPÈCES HOMÉOTHERMES ADULTES ET EN COURS DE CROISSANCE. Ann. Physiol. et Physiochim. Biol. 6: [721]–744, illus.

(16) Kleiber, M.
1935. THE CALIFORNIA APPARATUS FOR RESPIRATION TRIALS WITH LARGE ANIMALS. Hilgardia 9: 1–70, illus.

(17) Kriss, M.
1930. THE INSENSIBLE LOSS IN BODY WEIGHT OF CATTLE. Jour. Agr. Research 40: 271–281.

(18) ———
1930. QUANTITATIVE RELATIONS OF THE DRY MATTER OF THE FOOD CONSUMED, THE HEAT PRODUCTION, THE GASEOUS OUTGO, AND THE INSENSIBLE LOSS IN BODY WEIGHT OF CATTLE. Jour. Agr. Research 40: 283–295, illus.

(19) KUNO, Y.
1931. PERSPIRATIO INSENSIBILIS. Jour. Oriental Med. 15: [99]–122, illus.
(20) LEFÈVRE, J., and AUGUET, A.
1930. COMMENT L'ÉTAT HYGROMÉTRIQUE DE L'AIR PEUT INFLUENCER LE MÉTABOLISME. DE L'HYPOTONUS EN MILIEU CHAUD ET HUMIDE. Compt. Rend. Acad. Sci. [Paris] 190: 326–328.
(21) ——— and AUGUET, A.
1930. RAPPORTS SUR LE FONCTIONNEMENT DES LABORATOIRES DE LA STATION CENTRAL DE RECHERCHES SUR L'ALIMENTATION. I. LABORATOIRE DE BIOÉNERGÉTIQUE. Bull. Soc. Sci. Hyg. Aliment. 18: [328]–339, illus.
(22) LEVINE, S. Z., KELLY, M., and WILSON, J. R.
1930. THE INSENSIBLE PERSPIRATION IN INFANCY AND IN CHILDHOOD. II. PROPOSED BASAL STANDARDS FOR INFANTS. Amer. Jour. Diseases Children 39: [917]–929, illus.
(23) ——— and MARPLES, E.
1930. THE INSENSIBLE PERSPIRATION IN INFANCY AND IN CHILDHOOD. III. BASAL METABOLISM AND BASAL INSENSIBLE PERSPIRATION OF THE NORMAL INFANT: A STATISTICAL STUDY OF RELIABILITY AND OF CORRELATION. Amer. Jour. Diseases Children 40: [269]–284, illus.
(24) ——— and WILSON, J. R.
1927. RESPIRATION METABOLISM IN INFANCY AND IN CHILDHOOD. IV. ELIMINATION OF WATER THROUGH THE SKIN AND RESPIRATORY PASSAGES. Amer. Jour. Diseases Children 33: [204]–212, illus.
(25) ——— WILSON, J. R., and KELLY, M.
1929. THE INSENSIBLE PERSPIRATION IN INFANCY AND IN CHILDHOOD. I. ITS CONSTANCY IN INFANTS UNDER STANDARD CONDITIONS AND THE EFFECT OF VARIABLE PHYSIOLOGIC FACTORS. Amer. Jour. Diseases Children 37: [791]–806, illus.
(26) ——— and WYATT, T. C.
1932. INSENSIBLE PERSPIRATION IN INFANCY AND IN CHILDHOOD. IV. BASAL MEASUREMENTS IN DEHYDRATED INFANTS. Amer. Jour. Diseases Children 44: [732]–741, illus.
(27) MAGENDANTZ, H.
1932. ÜBER DIE BEZIEHUNGEN ZWISCHEN PERSPIRATIO INSENSIBILIS UND GRUNDUMSATZ BIE GESUNDEN UND KRANKEN. Deut. Arch. Klin. Med. 173: [44]–52, illus.
(28) MANCHESTER, R. C., HUSTED, C., and MCQUARRIE, I.
1931. INFLUENCE OF THE STATE OF HYDRATION OF THE BODY ON THE INSENSIBLE LOSS OF WEIGHT IN CHILDREN. Jour. Nutrition 4: 39–51, illus.
(29) MITCHELL, H. H., and HAMILTON, T. S. with the assistance of others.
1932. THE EFFECT OF THE AMOUNT OF FEED CONSUMED BY CATTLE ON THE UTILIZATION OF ITS ENERGY CONTENT. Jour. Agr. Research 45: 163–191, illus.
(30) NATIONAL RESEARCH COUNCIL.
1926–30. INTERNATIONAL CRITICAL TABLES OF NUMERICAL DATA, PHYSICS, CHEMISTRY AND TECHNOLOGY... 8 v., illus. New York.
(31) NEWBURGH, L. H., and JOHNSTON, M. W.
1934. RELATION BETWEEN DEHYDRATION AND THE INSENSIBLE LOSS OF WATER. Jour. Nutrition 7: 107–116.
(32) ——— WILEY, F. H., and LASHMET, F. H.
1931. A METHOD FOR THE DETERMINATION OF HEAT PRODUCTION OVER LONG PERIODS OF TIME. Jour. Clin. Invest. 10: 703–721.
(33) WILEY, F. H., and NEWBURGH, L. H.
1931. THE RELATIONSHIP BETWEEN THE ENVIRONMENT AND THE BASAL INSENSIBLE LOSS OF WEIGHT. Jour. Clin. Invest. 10: 689–701, illus.

VIABILITY OF CONIFER SEED AS AFFECTED BY SEED MOISTURE CONTENT AND KILN TEMPERATURE[1]

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INTRODUCTION

In collecting conifer seed to use in reforestation, the cones must be harvested before the scales open or the seed will drop out and be lost. After they are harvested, the green cones must be thoroughly air-dried before the scales will open sufficiently to release all of the seed. In some regions weather conditions may interfere with drying operations. This condition and the development of the forest-seed industry have brought into use the dry kiln with its wide range of temperatures as a more controllable means of opening freshly gathered, moist cones. Kiln operation in the drying of cones cannot, however, be governed by the sole aim of completing the run in the shortest possible time. Many organic compounds are more liable to be disorganized by heat when they have a high moisture content than when they are dry, and seeds may be expected to react in this way. That in some seeds disorganization from the application of heat is greatest when moisture content is high is well known, even from the rather meager specific data on the subject. Obviously, the kiln operator must know what temperatures he can apply without injuring the moist seed. Also, he should know whether he may not apply much higher temperatures after part of the cone and seed moisture has been driven off by moderate heat. The object of the study discussed here was to determine, for certain conifer seeds, what effect a gradual increase in heat may have on moist seed, and the relation of such effects to increase in the moisture content of the seed. Furthermore, it was desired to determine the critical combinations of heat, moisture, and duration of heating. Tests were made with seed already extracted by air-drying. Results from such tests, although not exactly comparable with those in actual practice, were regarded as clearly indicative of results to be expected in seed extraction.

REVIEW OF LITERATURE

The fact that certain dry seeds withstand higher temperatures than moist seed was reported by Eduard Heiden in 1859, Julius Sachs in 1865, and L. Just in 1875, according to citations by Atanasoff and Johnson (*1*).[3] Waggoner (*14*) later heated radish seed under a large number of different moisture content and temperature conditions and found also that the ability of the seeds to withstand heating varied inversely with their moisture content. For example, when seed of the Icicle radish, having a moisture content of more than 38

[1] Received for publication Nov. 20, 1935, issued July 1936.
[2] The experimental work for this report was done at the University of California, Division of Forestry. The writer received many helpful suggestions from F. S. Baker, A. W. Sampson, and A. R. Davis.
[3] Reference is made by number (italic) to Literature Cited, p. 864.

percent, was heated at 55° C. for one-half hour, the germination was subnormal, but when the seed-moisture content was only 0.4 percent, the germination was normal even after the seed was heated at 105° C. At 100° and more, the germination became less with each step of moisture increase above 0.4 percent.

Hottes and Wilson (*8*) obtained a moisture series similar to Waggoner's by placing wheat on trays in the upper part of jars which had various concentrations of sulphuric acid in the bottom. Despite the molding of samples with high moisture content, the investigators found that samples having 10 percent moisture, after being heated for 1 hour at 90° C. in a closed container, failed to germinate, but when heated at 80°, germinated 100 percent. Samples with 12 percent moisture gave no germination after heating at 80°, but 76-percent germination after heating at 70°. Germinating methods and sampling were not described.

Somewhat similar though less conclusive results were obtained by Harrington and Crocker (*6*), Kienholz (*10*), and Hofmann (*7*).

A number of investigators have studied the lethal temperatures for seed having a moisture content in equilibrium with ordinary storage conditions, but for the purposes of this study their work is of little value, since they made no record of either the air- or seed-moisture content. These include Atanasoff and Johnson (*1*), Burgess (*2*), Ewart (*3*), Gaine (*5*), Jodin (*9*), Robertson (*11*), Spafford (*12*), Staker (*13*), and Wright.[4] From these investigations dealing with lethal temperatures for seed of no stated moisture content, one can only conclude that with alfalfa, barley, wheat, oats, and acacia there is likely to be a decrease in germination after the seed has been subjected to about 90° C. for several hours, but seed from Douglas fir, ponderosa pine, peas, and cress evidently is injured at a lower temperature.

EXPERIMENTAL METHODS

MATERIAL USED AND NATURE OF TESTS

The seed used in this experiment was that of Douglas fir (*Pseudotsuga taxifolia* (LaMarck) Brit.) and ponderosa pine (*Pinus ponderosa*, Dougl.). It was purchased from a dealer in forest seed at Longview Wash., and was accompanied by declarations of origin. The fir seed came from an altitude of 700 feet in Cowlitz County, Wash. The pine seed was from Antelope Creek watershed, Siskiyou County, Calif., elevation 4,800 feet. Both kinds of seed were harvested in the fall of 1930 and had been extracted from air-dried cones.

The heating experiments were made in February 1931. The seeds were heated under 36 different combinations of conditions, including 3 known degrees of moisture, a long and a short period of heating, and 6 temperatures ranging by 5-degree intervals from 45° to 70° C. The percentage of germination from 5 samples, each containing 100 seeds, was used as the criterion of the result of each different treatment. Thus, a total of 180 germination tests was made. To obtain a basis for the choice of procedure, the effect of small changes in conditions and the reliability of the germination percentage were measured in preliminary experiments.

[4] WRIGHT, E. THE VIABILITY OF NATIVE AND EXOTIC SEED AT HIGH TEMPERATURES. Berkeley, Calif. 1923. (Thesis, Univ. Calif.)

ADJUSTING THE MOISTURE CONTENT

Three moisture conditions were chosen with the intention of having a maximum and minimum that are commonly encountered and an intermediate point to help determine any graduation of effects due to the moisture.

The driest sample came from seed stored in crocks under laboratory conditions, averaging 7 ± 0.5 percent moisture. The intermediate moisture condition was set at 30 percent, which represents that of seed in cones that have been stored for some time previous to extraction. The maximum moisture condition was set at 60 percent for the fir and 50 percent for the pine, because moisture of these percents approaches the greatest amount of water which these seeds will absorb and approximates the moisture content of freshly gathered cones.

A moisture content of 30 percent was obtained by soaking the Douglas fir seed in water for 35 minutes and the ponderosa pine seed for 3 hours. The moisture contents of 60 percent for Douglas fir seed and 50 percent for the pine were obtained by soaking the fir seed for 10 hours and the pine seed for 15 hours.

After the water was drained from the seeds, they were spread on a paper towel for approximately 5 minutes to allow the superficial water to dry. The seed was mixed and respread several times during the drying period, so that it would have a uniform exposure. When the coats appeared free from a water film, the seed was put in stoppered heating bottles and a 6-g sample set aside for a moisture determination (based on the constant weight after drying the sample at 90° C.) These checks showed that the seed classed as having 30 percent moisture actually had a range of ± 2 percent, and that classed at 50 or 60 percent actually had a range of ± 3 percent.

HEATING

The seed was heated at temperatures of 45°, 50°, 55°, 60°, 65°, and 70° C. in the upper part of a thermostatically controlled electric oven. By means of a small motor-driven fan, the desired temperature was maintained in all parts of the upper half of the oven with a variation of only $\pm 1°$.

The seed containers were glass bottles, the cork stoppers of which had a fine groove cut in the side to allow a balance with atmospheric pressure. The bottles containing the pine seed were 2 inches square and 4 inches tall, and those containing the Douglas fir seed were 1¾-inch round bottles, 3 inches tall.

It was desired to prevent any significant drying in the seeds during heating. Trial samples showed no appreciable loss in moisture content during a preliminary 10-hour heating period at 50° C., and moisture-content samples taken in the regular heating periods indicated that 2 percent was the maximum loss to be expected, this occurring in the samples which had 30 percent or more moisture at the beginning.

About 1 hour was required for the temperature at the center of a bottle of dry seeds to equal an oven temperature of 50° C.; therefore it was necessary to preheat the seed in a quick way. To do this, the glass containers were warmed, then the seed was introduced, and, with thermometers thrust through the stoppers, the bottles of seeds

were warmed in a small hot oven. The samples were constantly watched and shaken by hand so that uniform heating from the outside to the center would be obtained. The desired temperature generally was reached in 5 to 10 minutes, and the bottles were then quickly transferred to the main oven.

The thermometers in the bottles were allowed to project through the two ventilator holes in the top of the main oven and were checked frequently to avoid any accidental fall or rise in temperature. The temperatures within the bottles did not vary more than 1° C. Six bottles of seed usually were put in the oven at the same time so that seed representing three different moisture conditions and two different durations of heating were subjected to the same temperature.

To determine the effects of two different durations of heating, some of the bottles were removed from the oven at the end of half an hour, the rest remaining 3 hours. Upon removal, the seed was spread on paper towels to dry and cool for 24 hours, whereupon it was stored in unsealed envelopes for 1 week before the germination tests were made.

GERMINATION

Since it would be very difficult to measure the separate physiological changes within seed which had been heated, the ultimate effect of high temperature was judged by the percentage of germination after heating. To obtain a standard for comparison of effects, eight random samples of unheated seed taken from the same crock were germinated. To have these under representative sprouting conditions, four samples were placed in each of the two germinating chambers.

By means of a graduated test tube of small diameter, the seeds were measured into lots containing approximately 100 seeds each, and no accurate count was made until the end of the germination period. Each lot was put in a separate test tube to be soaked in water 24 hours, after which time the water was drained off and the sample was placed on an individual plate in the germination chamber.

The germination plates were rough-surface, 4- by 3-inch paper ice-cream plates that had been soaked in water for 3 weeks to make them thoroughly saturated when first put in the germinator.

The germinating equipment consisted of two automatically controlled, water-jacketed germinators, with eight wire shelves in a chamber 18 by 20 by 20 inches and a water-pan humidifier under the bottom shelf. Temperatures were maintained at 27° C. The atmosphere was saturated at all times to prevent excessive drying of the plates.

The samples were inspected at 5-day intervals by removing one shelf at a time and recording for each numbered plate the number of seeds having protruding sprouts. The recorded seeds were then discarded. If molds or midge fly larvae appeared on the plate, or if some of the radicles had started to wilt as a result of damping-off fungi, the observation was included in the notes, in order that any correlation between the presence of these associates and the seed viability might be discovered. If any of the plates needed moistening, they were sprayed with a fine jet of water.

The tests were continued for 60 days, whereupon it was estimated from cumulative germination curves that sprouting of viable seeds

was complete. Previous cutting tests had shown the original stock of pine seed to have from 7- to 30-percent culls. To determine accurately the germination percentage, it was necessary to know the number of fully developed seeds in each sample. This was done in the case of the ponderosa pine samples by cutting open the ungerminated seeds and eliminating the undeveloped specimens. Germination percentages were based upon the number of sprouted ponderosa pine seed plus the developed but unsprouted seed. From previous cutting examinations it was found that the original Douglas fir seed was 98-percent sound, and since most of the ungerminated Douglas fir seed in the sprouting tests had disintegrated before the end of 60 days, no careful cutting tests were made on them after germination, the original number in each sample being used as the basis for germination computations.

As the plates were inspected, the area of each plate covered by the black mold *Chaetomium elatum* was estimated in tenths; the ratio of seeds attacked by the white mold *Verticillium* sp. and the presence of midge larvae were recorded on a scale of 10; and the presence of crystals, as yet unidentified, noticed on some of the pine-seed coats, was indicated in the notes. Since the presence and amount of damping-off fungi, molds, fly larvae, and crystals later proved to have no correlation with the germination results, they will not be discussed further.

RESULTS AND DISCUSSION

ANALYSIS OF THE DATA

The first step in handling the data was to determine the final germination percentage of each of 360 samples, and, for each species, to average these percentages for the five samples which had the same moisture content and were heated at the same temperature for the same length of time. The standard deviation of the five samples for each treatment was computed and compared with the deviations of individual samples which occurred farthest from the average. None of the samples showed sufficient deviation from the mean to be rejected. The standard error (standard deviation of a mean) was also computed.[5] The final germination percent and the standard error of each are given in table 1.

After computing the final germination percentages, the cumulative germination percentage for each sample and the mean of the five duplicate samples was computed for the end of each 5-day period. These cumulative mean values are plotted in figures 1 and 2 to illustrate the progress of sprouting. The standard deviation of the five samples around the moving average formed by the cumulative mean values was computed for each curve and is shown in the figures.

To those who are accustomed to germinating agricultural crop seeds, the variations in the following tests may seem unusually large. However, it has been the experience of investigators using forest seed that tree seeds are more liable to give low germination percentages and highly variable results.

[5] By the formula, standard error $=\frac{\sigma}{\sqrt{N-1}}$.

TABLE 1.—*Average germination*[1] *of Douglas fir and ponderosa pine seed of given moisture content heated at various temperatures for 0.5 and 3 hours*

DOUGLAS FIR

Heating temperature (°C.) and period	7 percent moisture content	30 percent moisture content	50 percent and 60 percent moisture content	Heating temperature (°C.) and period	7 percent moisture content	30 percent moisture content	50 percent and 60 percent moisture content
45°:	*Percent*	*Percent*	*Percent*	60°:	*Percent*	*Percent*	*Percent*
0.5 hour	62±3.2	68±1.8	[2] 58±3.0	0.5 hour	61±1.7	0	0
3 hours	65±2.2	[2] 55±3.8	[2] 38±3.6	3 hours	64±4.3	0	0
50°:				65°:			
0.5 hour	62±3.0	60±2.8	37±1.2	0.5 hour	[2] 43±1.9	0	0
3 hours	57±4.5	25±3.1	1±0.6	3 hours	53±2.0	0	0
55°:				70°:			
0.5 hour	66±1.5	[2] 30±3.9	0	0.5 hour	11±2.8	0	0
3 hours	[2] 52±3.6	1±0.2	0	3 hours	18±2.3	0	0

PONDEROSA PINE

45°:				60°:			
0.5 hour	24±1.8	23±2.8	17±2.7	0.5 hour	18±1.5	2±0.5	4±0.6
3 hours	21±3.0	21±2.8	23±3.3	3 hours	21±1.8	0	0
50°:				65°:			
0.5 hour	21±1.3	25±1.8	[2] 18±2.4	0.5 hour	13±2.0	0	0
3 hours	22±2.2	19±2.8	[2] 9±1.4	3 hours	11± .9	0	0
55°:				70°:			
0.5 hour	[2] 19±2.2	[2] 16±3.5	17±1.9	0.5 hour	9±2.1	0	0
3 hours	[2] 17±2.1	[2] 3±0.6	0	3 hours	7± .7	0	0

[1] The significance of the mean is given in terms of the standard error of the mean. A range of 3 times the standard error above and below the mean of 5 observations includes, according to normal probability, 96 percent of all other means which might be obtained from additional samples of the same material (4).

[2] For the indicated seed moisture content and duration of heating, this value represents the first significant deviation from normal that resulted from increase in the temperature applied. The normal values were 68±1.8 percent for Douglas fir and 29±2.4 percent for ponderosa pine.

According to some authors, not only the final germination percentage at the end of a long period but also the germination that takes place within a short time should be considered as an indicator of the physiological condition of seed. Harrington and Crocker (*6*) found, in testing heated Kentucky bluegrass seed, that the germination, although it later equaled the normal, was subnormal during the early part of the germination period. To study such relationships for Douglas fir and ponderosa pine, the writer plotted germination percentages for 5-day intervals. From inspection of figures 1 and 2, it is apparent that the condition which Crocker and Harrington observed does not exist in the present experiment. In fact, it is reversed. Germination of Douglas fir seed heated while in a moist condition was, for the first 20 days, equal to that of the unheated samples. After 20 days the heated seed did not germinate at the same rate as the unheated samples. This is shown by the fan shape of the curves in figures 1, *B*, and 2, *A*. However, the pine-germination progress curves begin to show differences in seed viability by the fifth day and remain nearly parallel after that (figs. 1, *C*, and 2, *B*).

TOTAL GERMINATION RESULTS AND THEIR APPLICATION

In table 1 it is seen that dry (7-percent moisture content) Douglas fir seed was not injured by heating for 3 hours at 50° C., but if the moisture content was 30 percent, a great loss in germination occurred.

Also, dry seed heated at 60° germinated normally, but seed with 30 percent or more moisture content heated for one-half hour at the same temperature failed completely. A temperature of 50° is often used in seed-extraction kilns. If freshly gathered cones (which usually have a moisture content of much more than 30 percent) are put in a

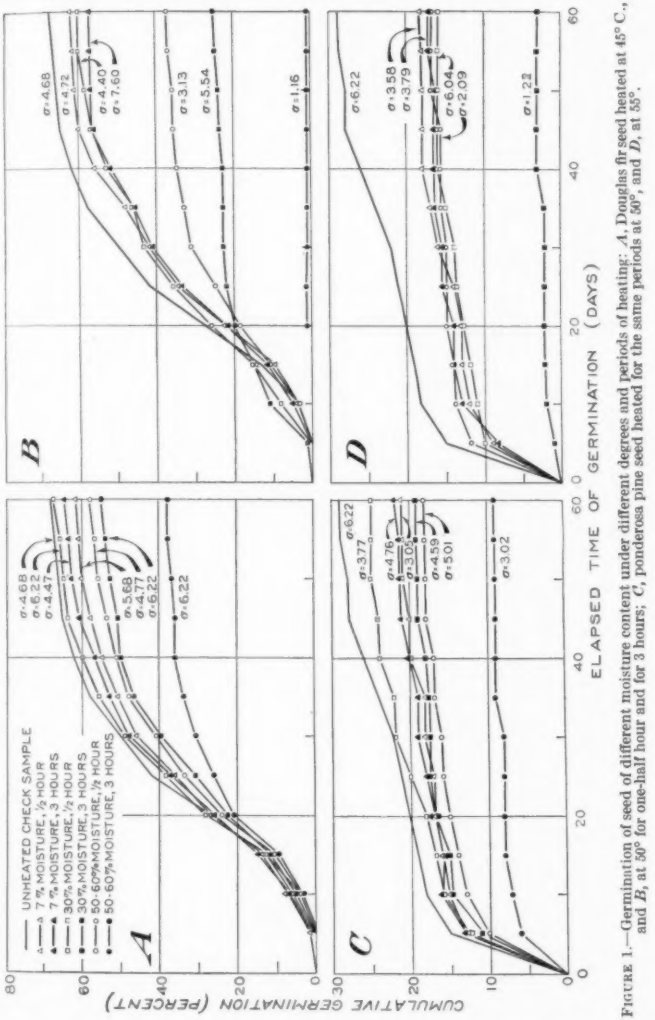

FIGURE 1.—Germination of seed of different moisture content under different degrees and periods of heating: *A*, Douglas fir seed heated at 45° C., and *B*, at 50° for one-half hour and for 3 hours; *C*, ponderosa pine seed heated for the same periods at 50°, and *D*, at 55°.

kiln at 50° and are not allowed free air circulation so that every cone with its seeds can dry out in less than 3 hours, probably the seed will be injured. If the moisture content is 60 percent when the cones are put in the kiln, the seed will probably be injured in less than one-half hour, unless it dries considerably within a few minutes.

It is possible that the relatively low temperatures which injure wet seed may reduce the germination of seed sown naturally. Surface soil temperatures often reach 50° C. in the fall when the soil and seeds are wet.

Table 1 shows that a temperature increase of 5° C. when heating Douglas fir or ponderosa pine seed may decrease the germination more than 30 percent. An increase from 50° to 55° C. caused a great loss

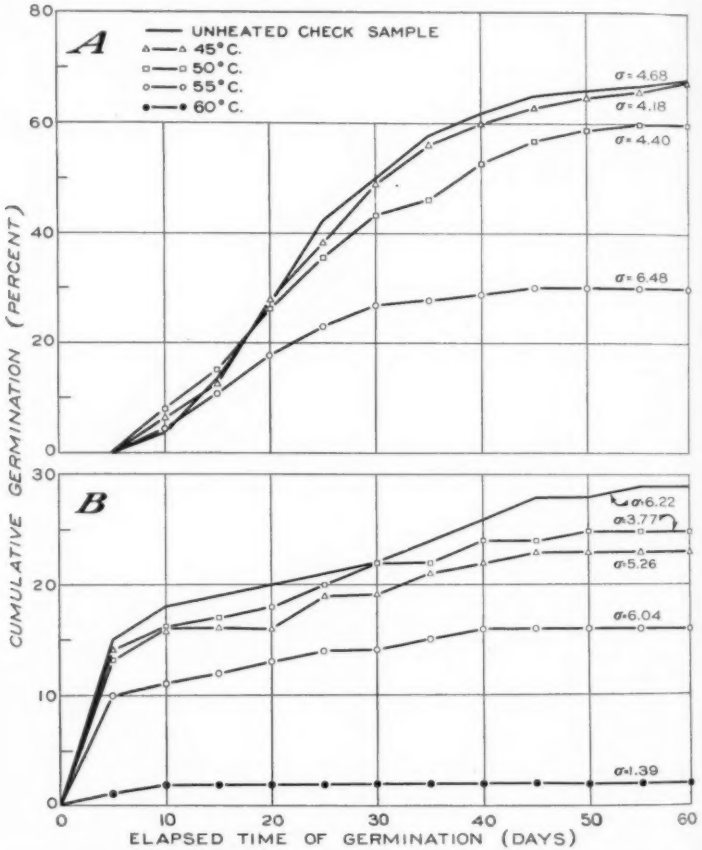

FIGURE 2.—Germination of seed which, at a moisture content of 30 percent, has been heated for one-half hour: *A*, Douglas fir; *B*, ponderosa pine.

in germination of Douglas fir seed when moisture content was 30 percent and the heating period was one-half hour, and a further increase of 5° caused a complete loss of viability. This indicates that care must be taken to keep all cones in a kiln at the same safe temperature. Temperatures at various places inside a drying chamber often differ by 5°. A temperature record taken at one point may indicate a safe condition while seeds at some other point are being destroyed.

The length of time that seeds are heated may have in some instances as great an effect on the viability as the seed-moisture content and heating temperature. When Douglas fir seed had a moisture content of 30 percent and was heated at 55° C., the germination after a ½-hour heating period was 30 percent, but after a 3-hour heating period was only 1 percent (table 1 and fig. 1, *A* and *B*). However, if the seed was dry, a 3-hour heating period had no appreciably greater effect than a ½-hour period. Apparently the heat resistance of dry seed is such that the initial damage is done in a short time, and no more injury is caused unless a very long heating period is used.

When dry Douglas fir or ponderosa pine seed (7-percent moisture content) is heated at 45° C. for one-half hour, the viability is not impaired. If the temperature, or seed moisture content, or time, or all three factors together, are increased unit by unit, there may be no evident effect on viability at first, but, ultimately, a combination of conditions is reached which causes a slight decrease in seed germination. This may be called a critical combination of conditions. Beyond that critical combination, any increase, either in heating temperature, seed-moisture content, or duration of heating, will cause a corresponding decrease in viability. It may be said that, in kiln drying, a slight increase in any one of these three factors is not dangerous unless the factors are already near a critical combination. But if cones are being dried near the critical heat point, the greatest care must be taken to avoid any increase in one of the three drying factors without a corresponding safe decrease in another factor It will be of prime importance to the kiln operator to know the critical combinations of heating conditions. Within the range of conditions tested in this experiment, the critical points exist at some combination of conditions slightly more moderate than those which caused the first significant losses, as shown in table 2.

TABLE 2.—*Summary of temperatures causing first significant injury of seed at different moisture contents*

Seed-moisture content and duration of heating	Douglas fir	Ponderosa pine	Seed-moisture content and duration of heating	Douglas fir	Ponderosa pine
7 percent:	° *C.*	° *C.*	50 percent (ponderosa pine):	° *C.*	° *C.*
½ hour	65	55	½ hour	----------	50
3 hours	55	50–55	3 hours	----------	45–50
30 percent:			60 percent (Douglas fir):		
½ hour	55	55	½ hour	45	----------
3 hours	45	50–55			

SUMMARY

From the results of this experiment on seed of ponderosa pine and Douglas fir a few general statements may be made concerning the practice of kiln-drying cones of these species before shaking out the seed. It seems imperative that there should be a thorough circulation of drying air around every cone. The cones should not be in piles, as this will keep the inside ones moist. There will be economy in spreading the cones in a thin layer so that they may dry more rapidly, for the sooner they dry, the less apt they are to be damaged by heat.

The drying should be begun with a relatively low temperature—40° C. for instance—which may be increased as the cones become drier. Near the end of the run the temperature probably can be

raised to 55° if the seed-moisture content has already been reduced to 20 percent or less. If the cones have been somewhat air-dried before they are put in the kiln, they may be started at a higher temperature than more moist cones. Moisture-content samples should be taken, and the sacks of cones should be graded according to moisture content, if the greatest efficiency of kiln operation is desired. When this is done, a batch of wet cones can be run at a low safe temperature and a charge of dry cones at a faster-drying but equally safe temperature. In that way it will not be necessary to extend the heating period of the dry cones in order to prevent injury to the seed of a few moist cones.

LITERATURE CITED

(1) Atanasoff, D., and Johnson, A. G.
1920. Treatment of cereal seeds by dry heat. Jour. Agr. Research 18: 379–390, illus.

(2) Burgess, J. L.
1919. Relation of varying degrees of heat to the viability of seeds. Jour. Amer. Soc. Agron. 11: 118–120.

(3) Ewart, A. J.
1908. On the longevity of seeds. Roy. Soc. Victoria, Proc. (n. s.) 21: 1–210, illus.

(4) Ezekiel, M.
1930. Methods of correlation analysis. 427 pp., illus. New York and London.

(5) Gain, E.
1922. Température ultra-maxima supportée par les embryons d'Helianthus annuus L. Compt. Rend. Acad. Sci. [Paris] 174: 1031–1033.

(6) Harrington, G. T., and Crocker, W.
1918. Resistance of seeds to desiccation. Jour. Agr. Research 14: 525–532.

(7) Hofmann, J. V.
1925. Laboratory tests on effect of heat on seeds of noble and silver fir, western white pine, and Douglas fir. Jour. Agr. Research 31: 197–199.

(8) Hottes, C. F., and Wilson, H. K.
1930. Resistance of wheat to high temperatures under different methods of heating. Jour. Amer. Soc. Agron. 22: 108–112.

(9) Jodin, V.
1899. Sur la résistance des graines aux températures élevées. Compt. Rend. Acad. Sci. [Paris] 129: 893–894.

(10) Kienholz, R.
1924. The effect of high temperatures on the germination and subsequent growth of corn. Philippine Jour. Sci. 25: 311–347, illus.

(11) Robertson, C. C.
1927. Notes on artificial extraction of seeds from cones of Pinus longifolia and Pinus patula. So. African Jour. Sci. 24: 320–327, illus.

(12) Spafford, W. J.
1930. Effects on germination of exposing wheat during heat waves. Jour. Dept. Agr. So. Aust. 33: 879–880, 882.

(13) Staker, E. V.
1925. The effect of dry heat on alfalfa seed and its adulterants. Jour. Amer. Soc. Agron. 17: 32–40.

(14) Waggoner, H. D.
1917. The viability of radish seeds (Raphanus sativus L.) as affected by high temperatures and water content. Amer. Jour. Bot. 4: 299–313, illus.

THE COMPARATIVE INSECTICIDAL EFFICIENCY AGAINST THE CAMPHOR SCALE OF SPRAY OILS WITH DIFFERENT UNSULPHONATABLE RESIDUES[1]

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INTRODUCTION

The percentage of the more chemically active constituents in a given mineral oil, as indexed by the unsulphonatable-residue test recommended by Graham (*5, 6*) [3] may indicate the approximate content of olefines or other unsaturated hydrocarbons, including aromatic, naphthenic, and resinous substances, as well as branched-chain paraffin compounds of high molecular weight. The large number of makes and grades of spray oils of the lubricating or engine oil type employed at present, together with the uncertainty about the chemical composition of each oil, prevents the making of a trustworthy comparison of the relative toxic effects of the above-mentioned active constituents on scale insects. However, although the different active constituents cannot be separated by the sulphonation test, it is possible to determine (by experiments) whether the more active compounds, as so measured collectively, have any effect upon the insecticidal action of the oils. Swingle and Snapp (*8*) have obtained data regarding the effect of several oils having different percentages of sulphonatable constituents, on the control of the San Jose scale (*Aspidiotus perniciosus* Comst.) on peach trees at Fort Valley, Ga., and report that wide variations in the content of sulphonatable materials produced little difference in toxicity to that insect. Their tests were conducted with oils containing sulphonatable portions ranging between 100 and 31.2 percent by volume. On the other hand, English (*4*) states that under some conditions the unsaturated oils may be more toxic.

Since any investigation of the toxicity of the sulphonatable constituents must be made with oils of both unknown and differing composition, it should be borne in mind that the results obtained in using a small number of oils are not necessarily applicable to all such oils. With recognition of this limitation, the laboratory and field experiments described below were planned. The objective was to determine whether or not three mineral oils containing markedly different percentages of sulphonatable material would produce measurably different mortalities of the camphor scale, *Pseudaonidia duplex* (Ckll.), at New Orleans, La. Spuler, Overley, and Green (*7*) report that the insecticidal value increases with the viscosity of oils; and, if such is the case, the effects of the sulphonatable portions, provided they influence the insect, should be separated from effects attributable

[1] Received for publication Feb. 12, 1936; issued July 1936.
[2] Authors' names are given in alphabetical order; the sequence indicates no seniority.
[3] Reference is made by number (italic) to Literature Cited, p. 878.

to viscosity. Hence oils were selected which had substantially the same viscosity and volatility in order that the effect of variations in these two properties would not obscure differences in results due to variations in the sulphonatable content.

EXPERIMENTAL METHODS

SPECIFICATIONS OF OILS

All sprays were prepared from two oils purchased from a well-known manufacturer and designated for experimental purposes as WR and L–1778. The Saybolt viscosities, the percentages of nonvolatile and of sulphonatable portions, and the specific gravities were separately determined and are presented in table 1.

TABLE 1.—*Characteristics of oils used in experiments with sprays against the camphor scale, New Orleans, La., 1932*

Oil designation	Saybolt viscosity at 100° F.	Nonvolatile material (24 hours at 100° F.)[1]	Sulphonatable material (by volume)	Specific gravity at 68.0° F.
	Seconds	*Percent*	*Percent*	
WR	94.9	98.6	6	0.8512
WR/L–1778	97.8	98.6	16	.8679
L–1778	101.9	98.4	33	.8846

[1] Evaporation tests were made according to methods proposed by Dawsey (2).

Distillation ranges were not determined, but according to the manufacturer's specifications the WR oil began distillation at 654° F. with 89 percent off at 750°, and the L–1778 began distillation at 630° with 87 percent off at 750°. The L–1778 was stated to be a blend of two or more straight-run oils. The oil designated as WR/L–1778 consisted of equal parts of the first and third oils, compounded by mixing them before preparing emulsions therefrom.

PREPARATION OF EMULSIONS

The emulsions consisted of the mineral oils dispersed in an aqueous solution of sodium oleate. Concentrated emulsions containing 66⅔ percent of oil by volume were made according to the process suggested by Dawsey,[4] wherein emulsification takes place spontaneously and the emulsifying soap is formed simultaneously. These emulsions were then usually diluted to an intermediate concentration of 40-percent oil before the highly diluted sprays containing from 0.9 to 2 percent of oil were prepared. The stock emulsions used throughout the work were numbered consecutively from 1 to 9, inclusive, and the sprays made from them were designated in a like manner.

Table 2 shows the composition of the sprays applied to potted camphor-tree (*Cinnamomum camphora*) plants in the laboratory. The stock mixtures were prepared 1 day prior to application of the sprays, the sprays being made up at the time of application by dilution with distilled water.

[4] DAWSEY, L. H. SPONTANEOUS EMULSIFICATION IN THE PREPARATION OF OIL SPRAYS. Unpublished manuscript.

TABLE 2.—*Composition of oil sprays used against the camphor scale on potted camphor-tree plants in the laboratory June 14 and Aug. 24, 1932*

Stock emulsion no.[1]	Oil used	Date of spraying	Composition of sprays			
			Spray no.[2]	Volume of stock emulsion taken	Oil content of spray	Normality of sodium oleate in aqueous phase×10⁴
				Cc	*Percent*	
1	WR	June 14	1a	50	1.0	6.62
			1b	85	1.7	11.34
2	WR/L–1778	do	2a	50	1.0	6.62
			2b	85	1.7	11.34
3	L–1778	do	3a	50	1.0	6.62
			3b	85	1.7	11.34
4	WR	Aug. 24	4a	45	.9	5.95
			4b	75	1.5	9.98
5	WR/L–1778	do	5a	45	.9	5.95
			5b	75	1.5	9.98
6	L–1778	do	6a	45	.9	5.95
			6b	75	1.5	9.98

[1] Each stock emulsion was made of 200 cc of oil, 4.3 cc of 3.05/N oleic acid, and 300 cc of distilled water, and had an oil content of 40 percent by volume.
[2] The total volume of the spray after dilution was 2,000 cc.

For the field sprays, both the oil concentration and the soap concentration were higher than in the laboratory sprays. The oil concentration was 2 percent and the emulsifier concentration (normality of sodium oleate in the aqueous phase) was 24.7×10^{-4}. The effect of increasing the oil content is to deposit a heavier film of oil on the tree. The effect of increasing the soap concentration is to decrease the oil deposit, but in this particular case, where 100 gallons of spray was made at a time, it was necessary to use New Orleans tap water, and an excess of soap was necessary to overcome its hardness and at the same time keep the oil globules in suspension.

Field-spray experiments (*1*) conducted in 1931 had shown that the kills most suitable for accurate mortality determinations (50 to 75 percent) might be obtained by using a spray containing 2 percent of oil (emulsified with potassium fish-oil soap) and having a soap normality of 26.3×10^{-4}. Effort was therefore made to approximate that composition in the field sprays. For each stock emulsion the oil was emulsified by the spontaneous method into a mixture containing 40 percent of oil. Two gallons of the oil was poured into a 15-gallon oak keg, to which a stirrer driven by a ¼-horsepower, 1,750-revolutions per minute motor was clamped; 0.0793 gallon (300 cc) of 3.05 normal oleic acid was stirred into the oil; 0.0817 pound of C. P. sodium hydroxide was dissolved in 1 gallon of distilled water, and this alkali solution was slowly added to the oleic acid-mineral oil mixture with fast mixing. After emulsification, 2 gallons more of distilled water was added and the whole 5 gallons of emulsion stored overnight in a large milk can for use in field spraying the following day.

These stock emulsions, nos. 7, 8, and 9, each containing 40 percent of oil (WR, WR/L–1778, and L–1778, respectively), were diluted with tap water to a final volume of 200 gallons to form sprays 7F, 8F, and 9F, each containing 2 percent of oil. The emulsifier concentration

(normality of sodium oleate in the aqueous phase) of 24.7×10^{-4} includes oleates of calcium, magnesium, etc., formed with undetermined quantities of mineral salts in the dilution water.

APPLICATION OF LABORATORY SPRAYS

The potted camphor-tree plants to which the laboratory sprays were applied had previously been artificially infested by the "box" method (*1*); so the populations were of uniform age distribution, and differences in the mortality of scales attributable to variation in age susceptibility were eliminated. The insects were in the adult stage at the time of spraying.

The laboratory spraying outfit consisted essentially of apparatus already described, and standardized conditions of spray application, like those described in the earlier paper (*1*), were maintained. The applications were made with a compressed-air sprayer consisting of a 2-liter metal tank, to which was attached a short piece of rubber hose fitted with a vermorel nozzle. The air-inlet pipe reached nearly to the bottom of the tank, so the incoming air provided sufficient agitation to insure an even distribution of oil within the tank. The infested plants were placed upon a revolving platform, at a distance of 1 meter from the nozzle, and each plant was sprayed for 24 seconds at a constant pressure of 40 pounds per square inch. The six sprays of the first set, numbered 1a to 3b (table 2), and containing 1 and 1.7 percent of oil, respectively, were applied on June 14. The other six sprays, designated 4a to 6b, were applied on August 24, but the oil concentrations were reduced to 0.9 and 1.5 percent, respectively, for the two series of the second set, because the scales of this brood were not so old as those of the earlier brood. Each set was treated as an independent experiment, since the applications were made at different times of the year. The number of plants composing the June 14 set was 46, of which 8 were sprayed with distilled water as checks; the number of plants composing the August 24 set was 42, of which 7 were sprayed with water as checks. The plants were from 15 to 20 inches in height and about 2 years old when sprayed.

APPLICATION OF FIELD SPRAYS

In the field sprays an entirely different technique was employed, the applications being made with a power sprayer of a type used in commercial work. The camphor-trees to be sprayed were located in Metairie Cemetery on both sides of a driveway running southwest and northeast. They were heavily infested with adult scales and ranged from 10 to about 25 feet in height. All were in the open and exposed to the sun at all times of the day. The trees along the drive were numbered from 1 to 10, going in the northeast direction, the numbers alternating from one side of the road to the other. Nos. 1, 6, and 9 were designated as check trees and were left unsprayed. The remaining seven trees were sprayed between 9 a. m. and noon on November 22. Spray 7F was applied on trees 2, 3, and 5; spray 8F on trees 4 and 7; and spray 9F on trees 8 and 10. Applications were

made with a power spray machine at 350 pounds' pressure. The time during which each tree was sprayed depended upon the size of the tree, and an attempt was made to secure uniform coverage or wetting of all parts of each tree. At the time of spraying a number (from two to five) of small branches on each tree were tagged as suitable for making counts and mortality determinations of the scales located thereon.

In order to determine whether any separation of the oil occurred in the spray tanks, samples were taken from the nozzle at the beginning and end of the application of each spraying and analyzed for oil content. These samples showed from 1.9 to 2 percent of oil. Since a difference of 0.1 percent is within the limits of accuracy of the method of sampling and analysis, it was concluded that no breakdown of the emulsions occurred while spraying, and that all trees received substantially the correct oil concentration.

RESULTS

OIL DEPOSITED BY SPRAYS

Since the previous work done in a study of the insecticidal action of emulsions at this laboratory (*1*) has shown that the percentage of insects killed is closely related to the quantity of oil deposited on the plant surface by the spray, analyses were made to determine the quantity of oil deposited on camphor-tree foliage by all sprays described herein.

At the time the potted plants were treated on June 14, portions of the same sprays were applied to pairs of branches from green camphor-trees. The number of leaves on the branches usually amounted to about 1,000. After being sprayed, the branches were allowed to dry, and from each branch (there were duplicate branches for each spray) approximately 500 leaves were clipped. These leaves were thoroughly mixed, and from each lot 200 disks 2 cm in diameter were stamped by means of a leaf die. The disk samples were then extracted with ether as the first step in the determination [5] (*3*) of the quantity of oil deposited by the respective sprays.

In the laboratory tests of August 24 the method of application of sprays to foliage more closely approximated the method by which the potted plants were sprayed. Branches cut from trees in the field were brought to the laboratory, and the smaller twigs were cut off and formed into bunches, which were then stuck into pots to simulate the potted plants. These were placed on the revolving platform and sprayed in the same way as the plants, except that the time of application was lengthened to 45 seconds because of the greater quantity of foliage. Table 3 shows the average volume of oil found per square centimeter of foliage, listed together with the sprays producing the deposit. (See table 1 for composition of these sprays.)

[5] DAWSEY, L. H. THE DETERMINATION OF UNREFINED MINERAL OILS RETAINED BY LEAF SURFACES FOLLOWING SPRAYING. Unpublished manuscript.

TABLE 3.—*Quantities of oil deposited on camphor-tree foliage by laboratory sprays, showing analyses of duplicate samples for each spray*

Sprays applied June 14, 1932				Sprays applied Aug. 24, 1932			
Spray no.	Analysis sample no.	Volume of oil deposited per square centimeter of leaf surface at 20° C.		Spray no.	Analysis sample no.	Volume of oil deposited per square centimeter of leaf surface at 20° C.	
		Volume found	Average volume			Volume found	Average volume
		Cc×10⁵	*Cc×10⁵*			*Cc×10⁵*	*Cc×10⁵*
1a	3	4.59	4.4	4a	3	4.04	4.1
	4	4.22			4	4.09	
2a	15	4.22	4.3	5a	15	4.17	4.1
	16	4.36			16	4.04	
3a	9	4.20	4.2	6a	9	3.77	3.8
	10	4.19			10	3.77	
1b	5	6.04	6.7	4b	5	5.74	5.7
	6	7.26			6	5.59	
2b	17	5.58	5.6	5b	17	5.74	5.7
	18	5.55			18	5.69	
3b	11	6.18	6.2	6b	11	4.85	4.8
	12	6.12			12	4.79	

The deposits produced by sprays 1a to 3a should be slightly greater than those of sprays 4a to 6a, inasmuch as the oil concentration in the former was 1 percent while in the latter it was only 0.9 percent. This appears generally to be the case for corresponding preparations in the sprays applied June 14 and those applied August 24. On the other hand, the average oil deposits of the "b" sprays, in each series, were higher than those of the "a" sprays in the same series, because the oil concentrations were much higher.

The disagreement between deposits from the sprays of equal strength, as shown in table 3, is not thought to be due to large errors in chemical analyses, since check samples containing known quantities of each oil were run simultaneously with the test samples. The lack of agreement is more likely to have been caused by nonuniform spraying of the duplicate tree branches, in spite of the precautions used in applying the sprays. A second source of error probably lay in the random difference in leaf surface as it affected the quantities of oil deposited. The question of lack of uniformity in coverage as being due to changing oil concentrations in the sprays during application was separately investigated for the laboratory sprays applied August 24. Samples of stock mixtures 4a to 6b (table 2) were placed in the reservoir of the spray apparatus, and the same volumes of spray liquids as were applied to each infested group of camphor plants were sprayed from the nozzle and caught in beakers for determination of the percentage of oil in each portion. There were six 300-cc portions in each case, including the liquid ejected at the beginning when the spray tank was full and the liquid at the end when the tank was nearly empty. If the oil globules actually had collected toward the top of the tank, the first portions of the spray would have been lower in oil content than the last portions, since the outlet pipe projected to the bottom of the spray reservoir. All tests made in this manner showed no change in the percentage of oil in the liquids, hence the trouble could not be located at this point. On the contrary, the oil-percentage determinations indicated that the quantity of oil

in the sprays as they left the nozzle of the apparatus could be controlled with high precision.

In preparation for the determination of the oil deposits produced by the field sprays, certain portions of each sprayed tree that offered the proper degree of infestation had been tagged prior to the spray application. Since mortality counts were to be made on these twigs, leaves from these twigs and from the immediate vicinity were detached after the sprays had dried, and disks 2 cm in diameter were cut from them. Duplicate samples of only 150 disks were taken from each tree, since the oil deposits on the foliage appeared to be heavy. The tagged, infested twigs, upon which the tips and younger shoots were left untouched, were left growing on the tree. The quantities of oil found in these samples are shown in table 4. Again, in these field sprays, differences in samples were found, but they are likewise attributed to small errors in analyses or to larger and unavoidable discrepancies due to nonuniform spray coverage.

TABLE 4.—*Quantities of oil deposited on camphor-tree foliage per square centimeter of leaf surface in field spraying,*[1] *as shown by analyses of duplicate samples from each tree sprayed*

Tree no.	Spray 7F	Spray 8F	Spray 9F	Tree no.	Spray 7F	Spray 8F	Spray 9F
	$Ce \times 10^6$	$Ce \times 10^6$	$Ce \times 10^6$		$Ce \times 10^6$	$Ce \times 10^6$	$Ce \times 10^6$
2	9.6			7		10.2	
	9.8					9.4	
3	10.6			8			10.2
	9.0						9.6
4		9.4		10			10.1
		8.9					10.6
5	8.7						
	10.4						

[1] Each spray contained 2 percent of oil. The soap concentration (normality of soap in the aqueous phase) of 24.7×10^{-4} includes oleates formed with sodium, calcium, magnesium, etc., in the dilution water.

DETERMINATION OF MORTALITY

Because of unavoidable delays in securing the proper oils, the scales at the time (June 14) of the first laboratory tests were reproducing by the time they were sprayed. If they had been kept under summer temperatures, many of the living scales would have deposited all their eggs and died before the mortality counts could have been completed, so it was necessary to retard the rate of development by subjecting the insects to low temperatures. The sprayed plants were placed in a cold room, where they were held at temperatures of 11° to 13° C. until the mortality had been determined. Counts were started June 29 and completed July 2, 18 days after spraying.

Earlier tests had shown that even lower temperatures did not cause any mortality of camphor scales when kept in the cold room for 3 weeks. In these preliminary cold-room tests, made earlier in the year, infested twigs were taken from camphor-trees in the field, the leaves removed, and the twigs (with the cut ends in water) were placed in the cold room, which was held at a temperature of 8° to 11° C. The natural mortality for one sample of these twigs was determined at the time of cutting, and for two other samples 15 and 21 days later. The results are given in table 5.

TABLE 5.—*Proportion of adult scales found alive on sample twigs on different dates, 1932*

Date counted	Period in cold storage	Overwintering adults counted	Adults alive
	Days	*Number*	*Percent*
Jan. 14	0	800	86.8
Jan. 29	15	779	84.2
Feb. 4	21	811	86.7

No significant changes in mortality were found; in fact, the counts made January 14 and February 4 showed unusually close agreement for duplicate samples from the field.

The counts were made in the manner described in a previous paper (*1*), but the methods of analyzing the data differed from those used

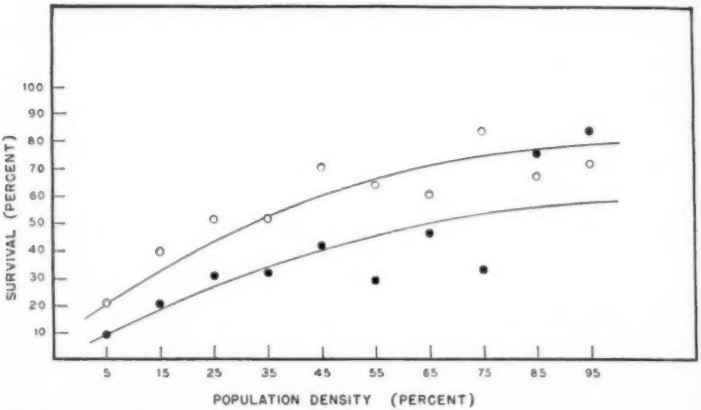

FIGURE 1.—Survival of camphor scales on potted camphor-tree plants sprayed June 14, 1932. The upper curve represents the average survival for the 1a, 2a, and 3a sprays, which contained 1 percent of oil. The lower curve represents the average survival for the 1b, 2b, and 3b sprays, containing 1.7 percent of oil. Open circles represent the average survival at different population densities for the 1-percent sprays; solid circles, the average survival for the 1.7-percent sprays.

in the earlier work. After determining the natural mortality at each population-density interval, the numbers of dead and living scales at each density were totaled for the plants sprayed with the same oil concentration. Corrections were made for natural mortality, and the percentages killed by the sprays estimated. In this way curves were obtained (fig. 1) which represented the average survival for the three oils at each oil concentration. Then the number surviving each oil was compared with the average survival for the three oils at the corresponding concentration, and the deviation from the average curve found at each density interval. To illustrate this procedure, a sample summary is shown in table 6. By taking the algebraic sum of the deviations, the differences in survival for the three oils were found. These differences were finally expressed as percentages of the total number of scales alive before spraying, as shown in table 7.

TABLE 6.—*Sample summary used in the estimation of relative effectiveness of sprays made from oils differing in sulphonatable content*

[The number of scales alive before spraying was obtained by multiplying the total number of scales at each population density by the percent alive in the check. The number expected to survive was estimated by multiplying the number alive before spraying by the average rate of survival at the corresponding density as shown in fig. 1. The data given are for spray 1a, containing 1 percent of oil]

Population density	Scales alive before spraying	Scales surviving	Scales expected to survive	Deviation	Population density	Scales alive before spraying	Scales surviving	Scales expected to survive	Deviation
	Number	*Number*	*Number*	*Number*		*Number*	*Number*	*Number*	*Number*
5 percent	82	14	17	−3	55 percent	96	57	64	−7
15 percent	113	45	37	8	85 percent	50	31	39	−8
25 percent	104	53	46	7	95 percent	92	73	74	−1
35 percent	82	46	43	3					
45 percent	146	102	88	14					

TABLE 7.—*Comparison of rates of survival of camphor scales on potted camphor-tree plants treated with sprays made from oils differing in sulphonatable content; sprays applied June 14, 1932*

Spray no.	Proportion of oil sulphonatable	Oil concentration in spray	Average oil deposit per square centimeter of leaf surface	Plants	Scales alive before spraying	Deviation from average survival curve	
						In scales surviving [1]	In rate of survival
	Percent	*Percent*	$Ce \times 10^5$	*Number*	*Number*	*Number*	*Percent*
1a	6	1.0	4.4	6	765	+13	+1.7
2a	16	1.0	4.3	6	504	+19	+3.8
3a	33	1.0	4.2	7	662	−18	−2.7
1b	6	1.7	6.7	6	671	+2	+.3
2b	16	1.7	5.6	6	557	−26	−4.7
3b	33	1.7	6.2	7	582	+26	+4.5

[1] The curves of fig. 1 were fitted so as to make the sum of the residuals approximately zero. Since in calculating the residuals the deviations from the curves were weighted by the square root of the number of scales at each density, the sum of the actual deviations as shown in this column will not necessarily be zero.

The methods of counting and analysis of the results of the sprays applied August 24 were the same as described for the June 14 sprays. Figure 2 shows the average survival curves for each of the two oil

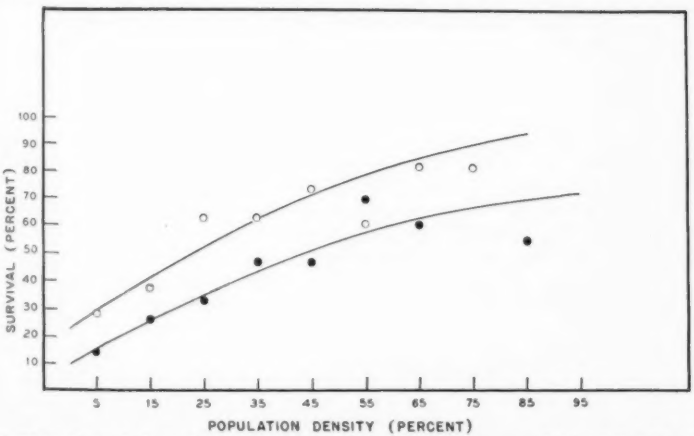

FIGURE 2.—Survival of camphor scales on potted camphor-tree plants sprayed August 24, 1932. The upper curve represents the average survival for the 4a, 5a, and 6a sprays containing 0.9 percent of oil. The lower curve represents the average survival for the 4b, 5b, and 6b sprays containing 1.5 percent of oil. Open circles represent the average survival for the 0.9-percent sprays; solid circles, the average survival for the 1.5-percent sprays.

concentrations. The deviations from these curves of the survival rates for each spray are given in table 8.

TABLE 8.—*Comparison of rates of survival of camphor scales on potted camphor-tree plants treated with sprays, made from oils differing in sulphonatable content; sprays applied Aug. 24, 1932*

Spray no.	Proportion of oil sulphonatable	Oil concentration in spray	Average oil deposit per square centimeter of leaf surface	Plants	Scales alive before spraying	Deviation from average survival curve	
						In scales surviving	In rate of survival
	Percent	*Percent*	*Cc*×10³	*Number*	*Number*	*Number*	*Percent*
4a	6	0.9	4.1	5	[1] 281	−9	−3.2
5a	16	.9	4.1	5	697	+6	+.9
6a	33	.9	3.8	6	839	−8	−1.0
4b	6	1.5	5.7	6	574	−42	−7.3
5b	16	1.5	5.7	5	1,093	+58	+5.3
6b	33	1.5	4.8	6	829	−22	−2.7

[1] Figures for this spray do not include 1 plant which showed only 21 percent dead (natural mortality in checks was 11.5 percent) and was inconsistent with the other 5 plants in this group. The reason for the low kill is unknown. Possibly the plant had a roughened bark instead of the usual smooth green bark. On such plants the kill is always lower. If this plant is included, the 4a spray shows a deviation from the average curve of 14.7 percent; the effect, therefore, would be to increase the variability of the results but not to indicate a difference due to the sulphonatable portion of the oil.

At the time the field sprays were applied the living overwintering scales were all adults, about 95 percent being in the pink and gravid stages. In making the counts from the field material the dead adults of the older broods and those attacked by predators or fungous diseases were classified separately. They were used in estimating the population density, but were then eliminated from further calculations. The proportion of dead immature scales was negligible, and such scales were not included in the counts.

Immediately before applying the sprays, infested branches were cut from the trees to be sprayed and the natural mortality was determined. No systematic variations in the proportion of dead scales were found throughout the rows. Counts were also made on branches of the check trees at intervals until the spray counts were completed, and no changes in the natural mortality were found during this time; accordingly, all the check counts were averaged to find the natural mortality at each population density. The proportion of dead scales in the unsprayed branches increased from 3 percent, when 5 percent of the twig area was covered by scales, to 8 percent when the population density was 95 percent.

From the natural mortality curve the number of scales estimated to be alive before spraying was found for each of the sprayed twigs, and from the number actually found alive the survival was calculated as a percentage of the number of scales alive before the application. The survival percentages are given in table 9 and are shown graphically in figure 3.

TABLE 9.—*Comparison of the rates of survival of camphor scales (at different population densities) on camphor-trees in Metairie Cemetery, after treatment, Nov. 22, 1932, with sprays 7F, 8F, and 9F, made from oils containing different proportions of sulphonatable compounds; together with data concerning quantities of oil deposited on leaves and some of the properties of the oils used*

SPRAYS USED

Spray no.[1]	Oil used	Saybolt viscosity of oil at 100° F.	Proportion of oil volatilized (24 hours at 100° F.)	Specific gravity of oil at 68° F.	Proportion of oil sulphonatable	Average volume of oil deposited per square centimeter of leaf surface
		Seconds	*Percent*		*Percent*	*Cc×10⁵*
7F	WR	94.9	1.44	0.8512	6	9.7
8F	WR/L–1778	97.8	1.42	.8679	16	9.5
9F	L–1778	101.9	1.59	.8846	33	10.1

RESULTS WITH VARIOUS SPRAYS

Population density (percentage of twig area covered by scales)	Checks		Spray 7F		Spray 8F		Spray 9F	
	Scales alive before spraying	Survival	Scales alive before spraying	Survival	Scales alive before spraying	Corrected survival	Scales alive before spraying	Corrected survival
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
0–10	501	96.9	299	20.7	282	43.6	253	21.3
10–20	1,008	96.1	673	32.2	785	46.4	843	33.3
20–30	1,336	95.8	736	49.5	900	54.9	1,129	47.1
30–40	1,068	95.6	831	62.2	938	65.6	811	49.9
40–50	800	94.9	632	57.8	680	75.9	914	62.7
50–60	918	94.6	410	78.0	408	76.2	827	57.6
60–70	642	94.0	272	71.7	339	92.0	585	72.0
70–80	390	90.9	216	70.4	193	81.3	236	68.6
80–90	298	93.4	149	71.1	92	100.0	329	74.2
90–100	361	91.6	133	58.6	42	81.0	357	73.1

[1] Each spray contained 2 percent of oil to 98 percent of soap solution which was 24.6×10^{-4} normal in soaps.

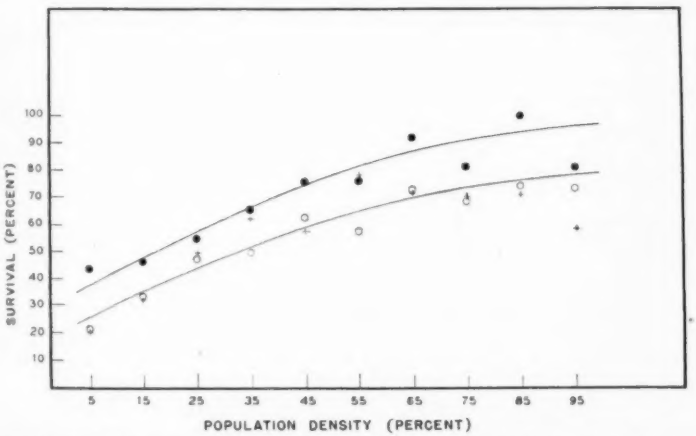

FIGURE 3.—Survival of camphor scales from oil sprays applied to camphor-trees. The lower curve represents the average survival for sprays 7F (WR oil) and 9F (L–1778 oil); the upper curve, the survival for spray 8F (containing a mixture of the two oils). Crosses represent survival from the WR oil spray; open circles, survival from the L–1778 oil spray; and solid circles, survival from the spray of the two oils mixed. Each spray contained 2 percent of oil.

From the curves of figure 3 it may be seen that the values at each density for the 7F and 9F sprays fell so close together that they could be fitted by one curve. The oils used in these sprays represented the two extremes in sulphonatable content. The survival from the 8F spray was uniformly higher over the entire range of population density. This oil was a mixture of the two other oils, and therefore intermediate in its properties. The average oil deposit from this spray was slightly lower than from the others, but the difference, although it may have been a contributing factor, was hardly sufficient to account for all of the difference in scale mortality. Other possible reasons might be differences in the texture of the bark, or more foliage on trees 4 and 7 to hinder the oil from reaching the twig surfaces where the scales were located.

DISCUSSION OF RESULTS

From the curves shown in figures 1 and 2 it was found that the average survival for the laboratory sprays containing 0.9 percent of oil ranged from 29 percent at a population density of 5 percent to 90 percent at a population density of 75 percent, and for the spray with 1.5 percent of oil, from 15 to 67 percent at the same population densities; for the 1-percent spray the survival ranged from 21 to 80 percent within the population density limits of 5 to 95 percent, and for the 1.7-percent spray, from 9 to 59 percent within the same limits. In the field sprays, when 2 percent of oil was used, the two oils of 6-percent and 33-percent sulphonatable content killed practically the same proportion of scales, the survival ranging from 25 to 78 percent over the entire population-density range, while for the oil containing 16 percent sulphonatable material the survival was 36 to 96 percent (fig. 3). The oil deposit on the leaves was considerably greater in the field applications, and it appears probable that a larger proportion of the oil was deposited on the foliage relative to that deposited on the twigs, by the field sprays than by the laboratory sprays.

The data given in tables 7 and 8 show no systematic differences in the laboratory tests which could be attributed to the sulphonatable portions of the oils used. In table 8, sprays 5a and 5b, in which the oil used was intermediate in its sulphonatable content, show slightly higher rates of survival than the other sprays in their respective groups. Otherwise the differences in the oil deposit and insect mortality appeared to be entirely random and well within the limits of variation ordinarily encountered in the effects of sprays where a comparatively low mortality is obtained. The results of the field sprays (table 9 and fig. 3) agree with those of the laboratory sprays in failing to show any differences in insecticidal efficiency resulting from differences in the sulphonatable portion of the oils. In all of these tests, therefore, no evidence was found that the sulphonatable portions of the oils had any effect upon the insecticidal action when the other physical and chemical properties of the sprays were uniform.

EFFECT OF OILS UPON PLANTS

Little concerning the relation between plant injury and refinement of the oil can be deduced from the laboratory spray tests, since small potted camphor-tree plants with few leaves and a heavy scale infestation may be much more easily injured than trees in the field. Of the

trees to which the field sprays were applied, only the two (nos. 8 and 10) sprayed with the oil containing 33-percent sulphonatable material exhibited any appreciable injury. On February 1 these had lost 75 to 80 percent of their leaves, whereas none of the others had had more than a 10-percent leaf drop. Freezing weather (20° F.) occurred on February 9, and on March 10 tree 10 was completely defoliated and tree 8 had only a few new leaves at the top. However, one of the trees sprayed with the mixed oil and one of the check trees had very few leaves also. The other trees were apparently normal. Other unsprayed trees throughout the city showed great variation in their resistance to the low temperature, and it is not known how much of the injury in the sprayed plot can be ascribed to increased susceptibility resulting from the oil sprays. However, the fact that trees 8 and 10 had by far the greater leaf drop before the freeze may indicate that under normal conditions the less refined oils are more toxic to camphor-trees.

SUMMARY

The comparative insecticidal value of three petroleum oils with 6, 16, and 33 percent by volume, respectively, of sulphonatable material was investigated in laboratory and field spraying tests. The oils were applied, in the form of emulsions containing from 0.9 to 2 percent of oil, sodium oleate soap being used as the emulsifier, to camphor-tree plants and trees infested with the camphor scale (*Pseudaonidia duplex* (Ckll.)). The other characteristics of the different oils were substantially the same, so that any detectable differences in scale mortality could be due only to differences in the sulphonatable portions.

When sprays which gave equal oil deposits were compared, the variations in mortality appeared to be entirely random, and no differences were found which could be attributed to the sulphonatable content of the oils.

For making comparisons between the toxicities of different oils, the first condition it was sought to satisfy was that of obtaining equal oil deposits on the plants. Analyses of the oil deposits left by sprays showed that substantially equivalent deposits were obtained when equal concentrations of the different oils were applied. In the laboratory tests the oil deposits produced were independent of the sulphonatable content of the oil but varied directly with the oil content of the spray, ranging from 3.8×10^{-5} cc per square centimeter of leaf surface for a 0.9-percent emulsion to 6.7×10^{-5} cc per square centimeter for a 1.7-percent emulsion. In the field spraying with emulsions containing 2 percent of oil the deposits ranged from 9.5×10^{-5} cc to 10.1×10^{-5} cc per square centimeter of leaf surface.

The average survival for the laboratory sprays containing 0.9 percent of oil ranged from 29 percent at a population density of 5 to 90 percent at a population density of 75 percent, and for the 1.5-percent sprays, from 15 to 67 percent at the same densities; for the 1-percent sprays, from 21 to 80 percent at densities of 5 to 95 percent; and for the 1.7-percent sprays, from 9 to 59 percent within the same density limits. In the field sprays, where 2-percent emulsions were used, the two oils containing 6 and 33 percent of sulphonatable material, respectively, killed the same proportion of scales, the sur-

vival ranging from 25 to 78 percent over the entire population-density range, while for an oil containing 16 percent of sulphonatable material the survival was from 36 to 96 percent.

No conclusion as to the effects of the oils on potted plants was practicable, inasmuch as such results would not be typical of reactions under field conditions; however, in the field tests the trees sprayed with 2-percent emulsions made with oil containing 33 percent of sulphonatable material showed a 75- to 80-percent leaf drop when observed 10 weeks after the spraying date. Trees sprayed with oils of lower sulphonatable content had a maximum leaf drop of less than 10 percent.

LITERATURE CITED

(1) Cressman, A. W., and Dawsey, L. H.
1934. Oil retention, oil-emulsifier ratio, and oil-water ratio as affecting the insecticidal efficiency of emulsions. Jour. Agr. Research 49: 1–19, illus.

(2) Dawsey, L. H.
1933. A laboratory method for determining approximately the evaporation of petroleum spray oils under field conditions. (Sci. note) Jour. Econ. Ent. 26: 735–736.

(3) ——— and Haas, A. J., Jr.
1933. A method for determining the quantity of mineral oil retained by leaf surfaces after spraying. Jour. Agr. Research 46: 41–49, illus.

(4) English, L. L.
1928. Some properties of oil emulsions influencing insecticidal efficiency. Ill. Nat. Hist. Survey Bull. 17: 235–259, illus.

(5) Graham, J. J. T.
1925. Report on insecticides and fungicides. Methods of analyzing oil emulsions. Jour. Assoc. Off. Agr. Chem. 8: 333–343.

(6) ———
1927. A study of the methods proposed for the determination of the unsulphonated residue in petroleum spray oils. Jour. Assoc. Off. Agr. Chem. 10: 124–130.

(7) Spuler, A., Overley, F. L., and Green, E. L.
1931. Oil sprays for summer use. Wash. Agr. Expt. Sta. Bull. 252, 39 pp., illus.

(8) Swingle, H. S., and Snapp, O. I.
1931. Petroleum oils and oil emulsions as insecticides, and their use against the San Jose scale on peach trees in the South. U. S. Dept. Agr. Tech. Bull. 253, 48 pp., illus.

TRANSMISSION OF SUGARCANE MOSAIC BY THE RUSTY PLUM APHID, HYSTERONEURA SETARIAE [1]

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INTRODUCTION

The spread of mosaic to supposedly resistant varieties of sugarcane such as Co. 281 and C. P. 807 during recent years, and the demonstration of the existence of various strains of the mosaic virus [3] have made evident the need for a detailed study of mosaic spread in Louisiana. This study includes not only the determination of general and specific factors in epidemiology, but a survey for possible additional vectors. Brandes,[4] in 1920, reported experiments showing that sugarcane mosaic was transferred by the corn leaf aphid (*Aphis maidis* Fitch). In this paper Brandes stated that the successful experiments with the corn aphis were of great interest scientifically, but added that it was "not believed that transmission of mosaic is restricted to this insect or to other aphids more abundant on cane." Brandes' findings concerning *A. maidis* were confirmed by other investigators. Despite attempts, by Brandes and later workers, at transmission with other insects, *A. maidis* has until recently remained the sole proved vector of sugarcane mosaic.

In 1930 the senior author began a study of the abundance of *Aphis maidis* in and around sugarcane fields to determine its relationship to the spread of mosaic in Louisiana. At the same time counts were made of other sucking insects found in such locations. Preliminary surveys showed that the rusty plum aphid (*Hysteroneura setariae* (Thomas)) was the most abundant of all aphids found on sugarcane in Louisiana. In view of its abundance and the fact that it had not previously been tried as a vector in the United States, transmission experiments were undertaken. This paper summarizes preliminary experiments showing that this aphid can transmit the mosaic of sugarcane.

GEOGRAPHIC DISTRIBUTION AND HABITS OF THE RUSTY PLUM APHID

Under the name of the rusty, or rusty-brown, plum aphid, *Hysteroneura setariae* apparently is distributed on plums, with grasses as alternate hosts, throughout most of the United States. Van Dine [5]

[1] Received for publication Feb. 19, 1936; issued July 1936.

[2] The authors gratefully acknowledge helpful suggestions from P. N. Annand, of the Bureau of Entomology and Plant Quarantine, and R. D. Rands, of the Bureau of Plant Industry.

[3] SUMMERS, E. M. TYPES OF MOSAIC ON SUGAR CANE IN LOUISIANA. Phytopathology 24: 1040-1042, illus. 1934.

——— STRAINS OF THE SUGARCANE MOSAIC VIRUS IN LOUISIANA. Fifth Cong. Internatl. Sugar Cane Technol. Proc. 1935. (In press.)

[4] BRANDES, E. W. ARTIFICIAL AND INSECT TRANSMISSION OF SUGAR-CANE MOSAIC. Jour. Agr. Research 19: 131-138. 1920.

[5] VAN DINE, D. L. A LIST OF THE INSECTS AFFECTING SUGAR CANE IN CUBA. Trop. Plant Research Found. Bull. 3, 16 pp. 1925.

states that it is generally distributed on sugarcane in Cuba, and Wolcott [6] reports its presence in Puerto Rico. The aphid has been generally found feeding on sugarcane and on other grasses in southern Louisiana. It has also been found feeding on plum twigs in this section, but plum trees are relatively rare around sugarcane fields. The rusty plum aphid feeds on grasses throughout the year in southern Louisiana. Following the low temperatures of the winter of 1934–35, a few individuals were found at all times feeding on perennial *Andropogon* sp. along cane-field ditchbanks.

On sugarcane these aphids are generally found on the collar lobe at the junction of the leaf blade and sheath, but sometimes also in the central whorl or on other parts of the plant. They are usually attended by ants that often form a protective dirt or borer-frass covering over them. They have been found on a large number of grasses that are common in and around cane fields, and some of these are also hosts of sugarcane mosaic. On the larger grasses the aphids are usually found feeding in the same positions as on cane; but on the smaller grasses, such as *Setaria lutescens* and *Eleusine indica*, they have been observed in all positions along the stem and even on the glumes.

The relationship of the rusty plum aphid to mosaic spread apparently has not been studied except by Loftin and Christenson [7] who, working in Cuba, reported the transfer of 10 to 60 *Hysteroneura setariae* from mosaic-infected sugarcane plants to each of 28 healthy plants of the susceptible varieties Cristalina and P. O. J. 2883. No mosaic appeared on any of these 28 plants.

EARLY EXPERIMENTAL WORK IN WHICH CAGES WERE USED

Because of very limited greenhouse space, a succession of experiments in small cages or other enclosures was first undertaken in which large numbers of aphids were simply colonized on mosaic-infected plants and left to find their way later to the authentic healthy plants placed alongside in the same cage.

A preliminary experiment was conducted in 1933 in which, under each of 14 lantern globes, one healthy and one infected plant, both of the variety P. O. J. 234, were caged together. Eighty individuals of *Hysteroneura setariae* were released in each of 5 of the globes, 40 *Aphis maidis* in each of 5, and 4 globes were held as checks. One new mosaic-infected plant developed in one of the globes confining *H. setariae*, two in those with *A. maidis*, and none in the checks. This experiment was conducted in an insect-proof greenhouse on ant-proof benches. The plants used were grown in sterile soil, and the healthy plants were from seed pieces that had been observed to be healthy for at least two vegetative generations.

Since this preliminary experiment incriminated *Hysteroneura setariae* as a possible vector, further experiments were instituted. The condensation of moisture and the high temperature in the lantern globes caused a heavy mortality of aphids. Additional experiments were, therefore, conducted in 3- by 4- by 4-foot, insect-proof, cloth cages, having small sliding glass doors through which observations

[6] WOLCOTT, G. N. THE MINOR SUGAR-CANE INSECTS OF PORTO RICO. Jour. Dept. Agr. Porto Rico, v. 5, no. 2, 47 pp., illus. 1921.

[7] LOFTIN, U. C., and CHRISTENSON, L. D. A REPORT ON THE CORN APHIS, APHIS MAIDIS FITCH, IN CUBA. Fourth Cong. Internatl. Sugar Cane Technol. Proc. and Bull. 115, 20 pp., illus. 1933.

were made. These cages were placed on ant-proof benches in an insect-proof greenhouse. As in the preceding experiment, the healthy seed cane had a mosaic-free record for at least two vegetative generations, and the plants were grown in sterile soil. Experiments conducted were as follows:

EXPERIMENT 1

On December 16, 1933, 18 healthy P. O. J. 234 cane plants were caged with 6 mosaic-infected Louisiana Purple plants. These plants were 4 to 8 inches in height and were all growing in 4-inch paper pots. A total of 750 *Hysteroneura setariae* collected from mosaic-free *Andropogon* sp. were released on the infected plants in the cage. On December 18 it was found that nearly all of the aphids had died as a result of having been parasitized. No mosaic had developed on the 18 plants by January 30, when the experiment was discontinued.

EXPERIMENT 2

Six mosaic-infected P. O. J. 36M plants in 5-gallon galvanized-iron cans and 10 healthy Louisiana Purple plants in 4-inch paper pots were caged together. These plants were all from 4 to 8 inches in height. In January 1934, 850 *Hysteroneura setariae*, collected from healthy *Andropogon* sp., were released on the infected plants in the cage. None of the healthy plants had developed mosaic at the time the experiment was discontinued in May 1934.

EXPERIMENT 3

Six infected P. O. J. 36M and fifteen healthy Louisiana Purple plants were caged together. On April 19 and 20, 1934, 750 *Hysteroneura setariae*, collected from healthy *Andropogon* sp., were released on the infected plants in the cage. One of the initially healthy plants showed mosaic on June 6, and two additional ones showed well-defined symptoms on July 6. Other healthy cane plants of the same age and source in the greenhouse remained free from the disease.

EXPERIMENT 4

Three mosaic-infected and four healthy P. O. J. 234 plants were transplanted together in can no. 1, and three infected and five healthy plants of the same variety were transplanted in can no. 2. These two cans were caged together and 600 *Hysteroneura setariae*, collected from healthy wild grasses, were released in the cage on August 24, 1934. In a second similar cage to be used as a check, three mosaic-infected and five healthy P. O. J. 234 plants were transplanted to can no. 3, and two infected and four healthy plants were transplanted to can no. 4. The healthy and mosaic plants in each of the four cans were separated by an 18-mesh wire screen from the bottom of the cans to about 4 inches above the surface of the soil. The purpose of this separation was to minimize any possibility of mosaic transfer by contact and to prevent mosaic-infected suckers from ermerging on the side where the healthy cane was planted. The cans used were of the 5-gallon galvanized-iron type. The plants were about 4 to 8 inches in height when the experiment was started. Three of the initially healthy plants in the aphid-infested cage had developed mosaic by September 30, a fourth by October 6, and a fifth by October 30. No

healthy control plants developed mosaic. Therefore, in this test five out of nine initially healthy plants in the infested cage contracted mosaic.

EXPERIMENT 5

Four healthy P. O. J. 36M plants were grown in each of sixteen 5-gallon cans in the greenhouse. On September 25, 1934, when these plants had reached a height of 12 inches, two cans were caged in each of eight insect-proof cloth and glass cages. These cages were 15 by 28 by 29 inches. In five of the cages 25 *Hysteroneura setariae* collected from mosaic-infected plants in the field were placed on each plant by means of a camel's-hair brush. Three cages were held as checks. None of the plants developed mosaic. This possibly may have been due to the large size and lack of vigor in the infested plants.

EXPERIMENT 6

One can containing four healthy P. O. J. 234 plants and another containing four infected Co. 281 plants were placed in each of six cages of the same type as used in experiment 5. The plants were from 4 to 10 inches tall. Six hundred *Hysteroneura setariae* were collected from healthy *Andropogon* sp. and released in each of three cages on January 30 and 31 and February 2, 1935. On February 12, 600 *Aphis maidis* collected from *Sorghum halepense* were released in a fourth cage. Cages 5 and 6 were held as checks. All cages were fumigated on March 7 and removed from the plants. At the time the healthy plants were discarded on May 2, no plant had developed mosaic.

It is believed that, in the six experiments listed above, the incidence of mosaic in the infested healthy plants was greatly lessened because the plants were covered by the cages for such long periods that their growth was usually retarded. For this reason they were probably less susceptible to the mosaic virus than succulent, vigorously growing young plants would have been. In all cages in which the aphids had been released, they were observed in the process of feeding to some extent on the sugarcane plants. Information on aphid activity in the cages is limited, owing to the difficulty of making observations in this type of cage. As is the case in the field, most of the rusty plum aphids fed on the collar lobe where the leaf sheath and blade join. It may be that the possibility of transfer by feeding on these tissues, especially in such slow-growing plants, is less than where feeding is done on more succulent tissues such as the leaf spindle. In all seven experiments, 9 of 109 healthy plants infested with *Hysteroneura setariae* from infected plants developed mosaic, and 2 of 9 plants similarly infested with *Aphis maidis* developed symptoms. None of the checks gave evidence of the disease, nor did any mosaic appear in other healthy plants from the same source that were growing in the greenhouse at the same time.

EXPERIMENTS IN WHICH GLASS TUBES WERE USED

In an attempt to increase the percentage of transfers by modifications in technique, aphids were confined for 24 hours on mosaic-infected plants in glass tubes one-half inch in diameter and 7 inches in length. The ones remaining alive were then transferred by means of a camel's-hair brush to healthy plants, where they also were confined in glass

tubes. The technique employed consisted of slipping a tube over the growing point of a plant and closing the lower end by packing cotton between the glass and the plant. Aphids were then placed on the plant, and the upper end of the tube was closed with cotton. In most instances the growing point did not extend to the upper end of the tube, and, of course, even the first collar lobe was excluded, and this situation forced the aphids to feed on other parts of the leaves. The aphids used were collected from mosaic-free grass plants in the field. Twenty to thirty aphids were released on each mosaic-infected plant, various susceptible varieties being employed, but the number remaining alive for transfer to healthy plants ranged from 2 to 25, with an average of about 12. Many of the aphids stuck to the sides of the tubes where moisture had condensed, and were incapacitated. The plants used in this series of experiments were from 5 to 6 inches in height and had been grown from cuttings planted in sterile soil in 4-inch clay pots. The mosaic-free cuttings were from commercial canes of susceptible varieties having a history of at least two known healthy vegetative generations. The infected plants upon which the aphids were confined were similar varieties of various known mosaic histories, in many cases the "strain" of virus involved having been previously determined.

During the course of each experiment the healthy plants with their attached tubes were confined in the 18-inch cages, previously described, up to the time when they were fumigated, usually after 6 to 9 days. The experiments were conducted in an insect-proof greenhouse on ant-proof benches. Following fumigation, the tested plants were held for from 60 to 150 days to ascertain definitely whether or not they had contracted the disease. The results of these experiments are given in table 1.

TABLE 1.—*Summary of mosaic-transmission attempts with 2 species of aphids, glass tubes being used for confining the insects on the plants*

Species of aphid	Transfer of aphids		Experiments conducted	Healthy plants used	Plants developing mosaic
	Date	Source			
			Number	*Number*	*Number*
Hysteroneura setariae	Nov. 19, 1934, to May 2, 1935	Mosaic sugarcane	15	56	2
		Healthy sugarcane	4	12	0
	May 5, 1935 [1]	Mosaic sugarcane	2	6	0
Aphis maidis	Mar. 1, 1935	Mosaic sugarcane	1	3	1
Checks (no aphids)	Apr. 5 to May 2, 1935		5	24	0
	May 5, 1935 [1]		1	7	0

[1] Silk bags, ½ inch in diameter, substituted for glass tubes.

Summarizing the experiments in table 1, it is seen that 2 cases of mosaic developed among a total of 62 plants that had been exposed to presumably viruliferous *Hysteroneura setariae*, and that there was 1 case among 3 plants infested by supposedly viruliferous *Aphis maidis*. The two transfers by *H. setariae* were obtained in an experiment in which 25 aphids were transferred from Louisiana Purple, infected with virus strain 2, on May 2, 1935, to each of 10 plants of healthy P. O. J. 213. The single transfer by *A. maidis* was the result of transferring 14 aphids which had been feeding on Mosaic Co. 281 (strain not determined) on March 1, 1935, to each of three healthy

P. O. J. 234 plants. No evidence of mosaic appeared in the checks in any of these experiments, or in other healthy plants from the same source that were growing in the greenhouse at the same time. No uncaged aphids were ever found in the greenhouse, which was fumigated periodically.

The plants in these experiments were allowed to remain in small pots, where they made poor growth owing to lack of root space and difficulty in getting the proper amount of moisture. This may have been responsible for the small number of mosaic transfers.

EXPERIMENTS IN 1935 IN WHICH LARGE CAGES WERE USED

Since it is well known that the expression of mosaic symptoms following infection depends upon further growth and unrolling of new leaves, transmission experiments were undertaken in which the plants employed were kept continuously vigorous. This was accomplished by transplanting them either to flats or beds in the greenhouse and giving them a fairly heavy nitrate fertilization. It was thought that shortening the feeding period of the aphids on the healthy plants to about 8 days and subsequently forcing the plants might increase the percentage of successful transfers with *Hysteroneura setariae*. A new series of experiments was, therefore, started in May 1935, in which pedigreed healthy plants growing in 4-inch pots of sterilized soil were transplanted to 14- by 24- by 6-inch flats of sterile soil after 8 days' exposure to viruliferous aphids. The flats were then fertilized and kept under the most favorable growing conditions possible.

In each of these experiments seven mosaic-infected plants were placed in insect-proof glass and cloth cages on ant-proof benches in the insectary. Thirty aphids collected from healthy grasses were placed on each plant with a camel's-hair brush. About 4 hours later eight healthy plants were placed in the cages alternating in position with the infected plants. Twenty-four hours later aphids were transferred from the infected plants to these healthy plants with a camel's-hair brush. To each healthy plant were transferred about 20 aphids which included a few that had in some instances moved from the diseased to the healthy plants prior to the transfers. They were allowed to feed for several days, after which all cages were fumigated. Check plants were given an exactly similar treatment except for the absence of aphids in the cages. Immediately following fumigation the plants with the surrounding soil were removed from the pots and transplanted to flats in the greenhouse, where they remained on ant-proof benches until discarded. Although regular examination were made, no aphids of any kind were ever found in the greenhouse.

As in previous experiments, the plants used were all of varieties known to be susceptible to mosaic. Known strains of the virus were used, whenever available, as a mosaic source, and field-run mosaic cuttings were used at other times. The cages employed in these experiments were 15 by 28 by 49 inches high and 16 by 30 by 33 inches high. All cages used in any given experiment were of the same size.

The results of this series of experiments are shown in table 2. In the transfer occurring in experiment H–1 the aphids had previously fed on Louisiana Purple plants infected with strain no. 1 of the mosaic virus, and in H–5 and H–6 they were from strain no. 2 mosaic infecting

C. P. 28/60. The aphids bringing about the remaining successful transmissions of the disease had fed on P. O. J. 234 infected also with strain no. 2 of the virus. It may be noted that out of 248 plants exposed, a total of 13 transfers of mosaic to originally healthy cane plants was secured in the cages in which *Hysteroneura setariae* was used as the vector. Of 60 healthy plants similarly infested with *Aphis maidis*, 14 developed mosaic. No transfers were observed in 68 check plants or in any plants of similar origin growing in the greenhouse in other experiments.

TABLE 2.—*Summary of mosaic-transmission trials with 2 species of aphids in large cages in 1935*

Experiment no.	Date of— Initiation	Date of— Termination	Aphid species used	Cages used	Plants used: Mosaic	Plants used: Healthy	Transfers of mosaic to healthy plants	Period since first exposure
				Number	*Number*	*Number*	*Number*	*Days*
H-1	May 18	July 27	*Hysteroneura setariae*	2	12	11	0	
			Aphis maidis	1	3	3	1	23
			Check	1	3	3	0	
H-2	May 22	July 27	*H. setariae*	1	6	7	0	
			Check	1	6	5	0	
H-3	May 8	July 31	*H. setariae*	1	6	3	0	
			Check	1	4	4	0	
H-4	May 31	Aug. 8	*H. setariae*	4	29	32	0	
			Aphis maidis	1	7	8	0	
			Check	1	7	8	0	
H-5	June 14	Sept. 2	*H. setariae*	6	42	38	3	15, 27, 39
			Aphis maidis	1	7	6	2	16, 18
			Check	1	7	4	0	
H-6	June 11	Sept. 11	*H. setariae*	3	9	4	0	
			Aphis maidis	2	6	5	1	35
			Check	2	6	4	0	
H-8	July 10	Sept. 11	*H. setariae*	4	28	31	3	21, 29, 30
			Aphis maidis	1	7	8	0	
			Check	1	7	8	0	
H-9	July 12	Sept. 11	*H. setariae*	5	35	38	0	
			A. maidis	1	7	8	0	
			Check	1	7	8	0	
H-10	July 22	Sept. 22	*H. setariae*	4	28	30	3	16, 36, 45
			A. maidis	1	7	6	5	15, 15, 16 21, 21
			Check	1	7	8	0	
H-11	July 23	Sept. 23	*H. setariae*	3	21	24	3	17, 20, 37
			A. maidis	1	7	8	5	2-17, 3-25
			Check	1	7	8	0	
H-12	Aug. 7	Oct. 7	*H. setariae*	4	28	30	1	30
			A. maidis	1	7	8	0	
			Check	1	7	8	0	

MISCELLANEOUS TRANSFER EXPERIMENTS

In August 1935, in an experiment similar to those listed in table 2, one of nine healthy C. P. 28/60 sugarcane plants developed mosiac following the release of 30 *Aphis maidis* per plant from mosaic-infected *Panicum dichotomiflorum*. None of six plants developed mosaic when similarly infested by *Hysteroneura setariae*.

The senior author found the green bug, or spring grain aphid (*Toxoptera graminum* Rond.), feeding on sugarcane in about equal numbers with *Aphis maidis* in some fields in 1934. In March 1935, 25 *T. graminum* collected from *Sorghum halepense* were confined in glass tubes on the whorls of each of three mosaic-infected Co. 281 cane plants for 24 hours. The surviving aphids were then transferred to whorls of three healthy P. O. J. 234 plants, where they were enclosed

in glass tubes for 24 hours and then fumigated. One mosaic transfer occurred, but there were no transfers in the four check plants in this experiment or in similar check plants in other experiments conducted at the same time.

In June 1935 an experiment similar to those listed in table 2 was started in which 30 *Toxoptera graminum* per plant were used as vectors checked against *Aphis maidis*. There was 1 mosaic transfer in 25 healthy C. P. 28/60 plants where *T. graminum* was transferred from mosaic C. P. 28/60, strain no. 2. No mosaic appeared in eight healthy plants to which *A. maidis* was transferred or in eight check plants without aphids. These two transfers suggest that *T. graminum* may be a vector of sugarcane mosaic, but additional experiments are necessary to prove this. This aphid often feeds in the whorls of sugarcane plants in the same manner as does *A. maidis*, for which, owing to its green color, it has no doubt often been mistaken.

Negative results have been obtained from transferring the following insects from mosaic-diseased sugarcane plants to healthy plants in the indicated number of cases: The yellow sugarcane aphid (*Sipha flava* Forbes), 8; the sharp-nosed grain leafhopper (*Draeculacephala mollipes* (Say)), 102; the fulgorid *Sogata furcifera* Horv., 5; and *Haplothrips graminis* Hood, 17.

DISCUSSION AND CONCLUSIONS

Results from the experiments reported here show that *Hysteroneura setariae* is a vector of sugarcane mosaic. From table 2 it is calculated that 5.2 percent of the healthy plants developed mosaic when infested with viruliferous *H. setariae*, and 23.3 percent developed mosaic when infested with *Aphis maidis*. These limited data indicate that *A. maidis* is several times more efficient than *H. setariae* as a vector of mosaic.

In all these experiments a higher percentage of transmission might have been obtained with more adequate equipment which would have promoted faster plant growth and consequent expression of symptoms and which would have given more suitable conditions for aphid feeding and multiplication. In spite of improved conditions for the growth of experimental plants reported on in table 2, the incubation periods for both vectors are unusually long. Furthermore, the time required for the appearance of symptoms is seen in the table to have been somewhat longer in most instances for *Hysteroneura setariae* than for *Aphis maidis*. While the differences may have been purely accidental, in view of the small number of direct comparisons, nevertheless a longer incubation period for *H. setariae* might be anticipated since it generally feeds on the collar lobe, which is, of course, less directly connected with the growing point than the young leaf whorl where *A. maidis* feeds.

Proof of mosaic transfer by the rusty plum aphid further complicates the problem of combating mosaic spread in sugarcane. While sugarcane is a natural host for *Aphis maidis* in Louisiana for only a short period in the winter and early in the spring, when other host material is unavailable or scarce, it is one of the preferred hosts of *Hysteroneura setariae* throughout the year. Furthermore, as already mentioned, several grasses bordering cane fields are also acceptable hosts of *H. setariae*. Its role as a vector probably explains several

specific instances of mosaic spread in early summer when frequent inspections showed the entire absence of *A. maidis*, and therefore the abundance of new infections could not be ascribed to this well-known vector.

It seems possible that *Toxoptera graminum* may also prove to be a vector of mosaic, as indicated by two successful transmissions in these experiments. This would be favored by its habit of frequently feeding in the central whorl of the cane plant.

SUMMARY

Until 1933 the corn leaf aphid (*Aphis maidis*) had been the only proved vector of sugarcane mosaic, but preliminary experiments in that year showed that the rusty plum aphid (*Hysteroneura setariae*) was also capable of transmitting the disease.

The rusty plum aphid is generally distributed on plums throughout most of the United States, with grasses as alternate hosts. On sugarcane plants it usually feeds at the collar lobe at the junction of the leaf blade and the sheath.

A series of experiments showed that out of 109 healthy plants infested with *Hysteroneura setariae* taken from infected plants, 9 developed the mosaic disease, while 2 out of 9 plants similarly infested with *Aphis maidis* developed symptoms of the disease. A second series of experiments gave 2 transmissions out of 62 exposures with *H. setariae* and 1 out of 3 with *A. maidis*. Another series showed 13 transmissions out of 248 exposures with *H. setariae* and 14 out of 60 with *A. maidis*. Two transfers of the mosaic were made by the feeding of the green bug (*Toxoptera graminum*) after the exposure of 28 healthy plants.

Although not so effective as *Aphis maidis* in transmitting the mosaic, *Hysteroneura setariae* is present and feeding on the cane throughout the year, whereas the former is present only in the winter and early in the spring.

THE COMPOSITION AND DIGESTIBILITY OF MUNG-BEAN SILAGE, WITH OBSERVATIONS ON THE SILICA-RATIO PROCEDURE FOR STUDYING DIGESTIBILITY [1]

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INTRODUCTION

Bergeim (*3*) [2] in 1926 employed a modified procedure for determining the apparent digestibility of food. The method consists of the addition to the food of known amounts of iron oxide or other suitable substance which is eliminated with practical completeness in the feces. The digestibility of any food substance is determined from the ratio of food substance to iron in the food and in the feces. The fecal ratio divided by the food ratio multiplied by 100 gives the percentage of food substance undigested. In practice it is not necessary by this method to measure accurately the total amount of food eaten or feces excreted during an experimental period inasmuch as one is dealing with a change of ratios and not with absolute amounts.

During a study of the digestibility of the proteins of cottonseed (*6*) Bergeim's method yielded results slightly lower than those obtained by the usual method in which the total amounts of protein consumed and excreted during an experimental period were determined. The lower results were attributed to the incomplete recovery of iron in the feces. By substituting silica for iron oxide and determining the silica ratios in the food and feces, results were obtained which were in close agreement with those obtained by the usual method (*7*). The experiments were conducted with rats on a diet which contained 1 percent of added silica.

In recent experiments with cows on a ration which contained approximately 3 percent of naturally occurring silica and 0.5 percent of added iron oxide results were obtained which indicated that the silica naturally contained in the feed was superior to iron oxide as a key substance in digestion studies (*8*). Bergeim (*4*) reports that Wildt fed sheep wheat straw and used the silica naturally contained therein as an index substance in absorption studies.

Recently the authors had occasion to determine the apparent digestibility of mung-bean silage. Since this feed contained approximately 20 percent of silica (dry-matter basis) or more than six times the amount present in rations previously employed (*8*) it appeared of interest to make the digestion studies by both the silica-index procedure and the usual method. It is the purpose of the present paper to report the results of these studies and to point out likely sources of error in the silica-ratio procedure.

Only one analysis of mung-bean silage is reported by Henry and Morrison (*9*), and so far as the authors are aware, no determinations have been made of its digestibility.

[1] Received for publication Nov. 5, 1935; issued July 1936.
[2] Reference is made by number (italic) to Literature Cited, p. 894.

MATERIAL AND METHODS

The silage was made from Golden mung beans, a tall variety which produces few seed pods. The plants were cut and ensiled before they had fully matured, while the bean pods were still green. The silage when taken from the silo had a characteristic but not unpleasant odor and in this respect differed from silage made of many of the legumes. On drying, it developed a pungent odor.

Weekly samples of silage were taken from the silo for several months previous to the digestion trial, and these were combined to form three composite samples representing material from the upper, middle, and lower parts of the silo. The samples were dried and reserved for analysis.

Nine 1-pound samples were taken from the lower part of the silo for silica and proximate analysis at the time the digestion trial was in progress.

The experimental animals were four milk cows, three of which had received mung-bean silage in their ration for several months previous to the digestion trial. They were stanchioned in the barn during the entire trial except for about 30 minutes each day, when they were exercised in a dry lot in the presence of a caretaker. The digestion trial was of 17 days' duration, 10 days' preliminary and 7 days' experimental. During the first part of the preliminary period the maximum amount of silage which the cows would consume was determined. During the 7-day experimental period, the silage was fed four times daily in four equal portions. In this way uneaten residues were avoided.

During the experimental 7-day period feces collections were made by hand. The total amount of feces voided daily was weighed and a one-twentieth aliquot taken for analysis and dry-matter determinations. A tenth of the one-twentieth aliquot was preserved in acid alcohol for nitrogen determinations. To obtain data on the constancy of the silica output, a small sample of each defecation from each cow was taken during a 24-hour period. All analyses of feed and feces were made according to methods adopted by the Association of Official Agricultural Chemists (*1*).

RESULTS

The average composition of mung-bean silage calculated from the analysis of three composite samples was found to be as follows: Moisture, 67.33 percent; crude protein, 4.81; crude fiber, 7.26; fat, 1.38; nitrogen-free extract, 13.12; and ash, 6.10 percent.

The percentage composition of mung-bean silage used in the digestion trial and the percentage composition of the feces voided by cows receiving the silage are given in table 1. The figures given in this table were used in calculating the digestibility coefficients presented in table 2.

The composition of mung-bean silage as given in table 1 differs appreciably from that reported by Henry and Morrison (*9*) in the percentage of ash and crude fiber, being higher in ash and lower in crude fiber. These authors report the ash and crude-fiber content of silage made from "nearly mature" mung beans as 1.2 and 9.8 percent, respectively. This difference between the two silages may be attributed in

part to varietal differences in composition of the plants and possibly to the manner in which they were handled before ensiling. Unless the plants are cut before the pods begin to turn brown many of the leaves and pods shatter when handled. The loss of leaves tends to decrease the percentage of ash and increase the percentage of fiber in the hay.

Foreign material may have contributed to the high ash content of the silage used in the present study since the plants were grown during a dry, dusty season. Approximately 75 percent of the ash in the silage was silica. Silica constituted only about 45 percent of the ash in the composite samples of silage. Similarly about 50 percent of the ash of wheat straw and 30 percent of the ash of timothy hay is silica. Analyses of soybean silage compiled by Becker et al. (*2*) show the ash content of this material to vary between 8.71 and 19 percent of the dry weight.

TABLE 1.—*Composition of mung-bean silage and of feces voided by cows which received the silage during a 7-day digestion trial*

Material analyzed and cow no.	Moisture	Crude protein	Crude fiber	Ether extract	Nitrogen-free extract	Ash
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Original silage	72.67	3.79	5.21	1.24	9.86	7.23
Dry silage		13.88	19.07	4.56	36.04	26.45
Cow 1: Dry feces		11.98	17.77	2.23	25.89	42.13
Cow 2: Dry feces		11.29	17.70	2.22	26.84	41.95
Cow 3: Dry feces		12.08	18.04	2.26	28.47	39.15
Cow 4: Dry feces		11.13	19.02	2.41	29.64	37.80

TABLE 2.—*Dry matter and nutrients ingested, voided, and digested during a 7-day period by cows on mung-bean silage*

Cow no. and items compared	Dry matter	Protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
Cow 1:						
Consumed ..... kilogram	46.8602	6.5042	2.1368	8.9362	16.8884	12.3945
Voided ..... do	25.4079	3.0439	.5666	4.5150	6.5781	10.7043
Digested ..... do	21.4523	3.4603	1.5702	4.4212	10.3103	1.6902
Do ..... percent	45.7	53.2	73.4	49.4	61.0	13.6
Cow 2:						
Consumed ..... kilogram	52.0672	7.2269	2.3743	9.9292	18.7650	13.7717
Voided ..... do	27.7243	3.1301	.6155	4.9072	7.4415	11.6303
Digested ..... do	24.3429	4.0968	1.7588	5.0220	11.3235	2.1414
Do ..... percent	46.7	56.6	74.0	50.5	60.3	15.5
Cow 3:						
Consumed ..... kilogram	31.2401	4.3361	1.4245	5.9575	11.2589	8.2630
Voided ..... do	16.4404	1.9860	.3716	2.9658	4.6806	6.4364
Digested ..... do	14.7997	2.3501	1.0529	2.9917	6.5783	1.8266
Do ..... percent	47.3	54.2	73.9	50.2	58.4	22.1
Cow 4:						
Consumed ..... kilogram	31.2401	4.3361	1.4245	5.9575	11.2589	8.2630
Voided ..... do	18.4581	2.0544	.4448	3.5107	5.4710	6.9772
Digested ..... do	12.7820	2.2817	.9797	2.4468	5.7879	1.2858
Do ..... percent	40.9	52.6	68.7	41.0	51.4	15.5
Average, digested ..... do	45.2	54.2	72.6	47.8	57.8	16.7

DIGESTIBILITY DETERMINED BY USUAL METHOD

Table 2 contains data on the dry matter and nutrients eaten, voided, and digested by cows receiving mung-bean silage. With but few exceptions, the digestibility figures obtained with the individual cows are in close agreement. Cow 4 gave the lowest values for all constituents except ash.

A comparison of the digestibility coefficients presented in table 2 with those reported for many other silages shows that the digestibility of the dry matter in mung-bean silage is low, being 45.2 percent. The average digestibility of dry matter in corn, cowpea, kafir, soybean, and vetch silage varies from 55 to 69 percent (*9*). The digestibility of the fat is relatively high. The digestibility of the protein, 54.2 percent, is about the same as that of corn and cowpea silages but less than that of soybean silage. The digestibility of the crude fiber, 47.8 percent, is less than that of corn silage and about the same as that reported for cowpea and soybean silages.

From the results given in table 2, the pounds of digestible nutrients in 100 pounds of fresh mung-bean silage containing 72.7 percent of moisture have been calculated to be 2 pounds of protein, 8.2 pounds of carbohydrates, and 0.9 pounds of fat.

Data on breed, age, average weight, and feed consumption of the cows are given in table 3.

TABLE 3.—*Age, breed, weight, and feed consumption of cows used in digestion trial*

Cow no.	Age		Breed	Average weight [1]	Fresh silage consumed daily	Total digestible nutrients consumed daily
	Years	Months				
				Pounds	*Pounds*	*Pounds*
1	5	7	Ayrshire	1,157	54	6.64
2	5	4	Guernsey	885	60	7.38
3	6	2	Jersey	717	36	4.43
4	4	0	do	775	36	4.43

[1] Average of 8 weights taken during the digestion trial.

DIGESTIBILITY DETERMINED BY SILICA-RATIO PROCEDURE

A uniform distribution of silica in the feed is essential for the determination of the apparent digestibility of a food substance by the silica-ratio procedure. It is likewise essential that the silica follow the food through the intestinal tract without stratification and that it be eliminated in like proportion in all parts of the feces. If this is the case, random samples of feces may be taken without making total collections.

Separate samples of the silage taken at the time the digestion trial was in progress showed considerable variation in silica content. On a dry-matter basis, the minimum silica content of nine 1-pound samples was 18.34 percent; the maximum, 22.54 percent; and the average, 19.91 percent. The percentage of silica was unrelated to the percentage of other constituents except ash, and no regular variation was observed in the silica content of samples taken on consecutive days. The variations that did occur and that were considered significant resulted in all probability from the uneven

distribution of silica in the silage. They represent sources of error in the procedure in that the food substance to silica ratio of the silage is not constant from day to day. This error was not encountered in previous experiments in which silica was present in smaller amounts and was well distributed in the feed (*8*).

The silica content of separate collections of feces from a single animal during a 24-hour period showed even wider variations. For example, the minimum silica content, the maximum, and the average of feces voided by cow no. 1 during the digestion period were 20.36, 29.61, and 26.20 percent, respectively, on a dry-matter basis. Variations of the same order were observed in the 24-hour samples of feces from the other three cows. Since with the exception of ash, the percentage of food constituents in the feces remained fairly constant during the 24-hour period, these variations in silica content produced variations of equal magnitude in the food substance silica ratios. Digestibility coefficients calculated from these ratios therefore showed no agreement, and it became evident that under these experimental conditions random sampling of feces was not good practice.

Since composite samples of the total amount of feces voided by each cow during the 7-day experimental period were available, silica determinations were made on these and digestibility coefficients obtained which were slightly lower than those obtained by the usual method. Thus the digestibility of the protein calculated from the silica ratio was 48.06 percent for cow 1; 50.65 percent for cow 2; 45.34 percent for cow 3; and 45.34 percent for cow 4. In these calculations the average silica content of the dry silage, 19.91 percent, was used.

Consistently low digestibility coefficients calculated by this method indicate an incomplete recovery of silica from the feces and suggest an appreciable metabolism and subsequent elimination of silica through other channels. Forbes (*5*) observed a retention of silicon by milking cows and suggested that storage took place through the growth of hair. He also observed an excretion of small amounts of silica in the urine but none in the milk.

In the present experiment over 85 percent of the calculated amount of silica ingested was recovered in the feces. This apparent metabolism of natural-occurring silica contributes a serious error to the method of study.

That under the conditions of this experiment the silica-ratio procedure for studying digestibility had no advantage over the older method of procedure is obvious. That under more favorable conditions the method is capable of yielding accurate results has been demonstrated in previous experiments (*7*, *8*).

SUMMARY

The apparent digestibility of mung-bean silage is reported for the first time. The digestion experiments were carried out with four milk cows receiving a ration composed solely of mung-bean silage. The fresh silage contained 3.79 percent of crude protein, 5.21 of crude fiber, 1.24 of fat, and 9.86 of nitrogen-free extract. The average digestibility coefficients were 45.2 for dry matter, 54.2 for protein, 47.8 for crude fiber, 72.6 for fat, and 57.8 for nitrogen-free extract.

It was found that the short method for studying digestibility which makes use of the change in ratio of food substance to silica in the feed as it passes through the intestinal tract was not applicable under the conditions of this experiment. The food substance to silica ratio of the feed varied from day to day. The same ratio in the feces showed wide variations during a 24-hour period, making the random sampling of feces impossible. The cause of these irregularities was not determined but was presumed to be due to (1) an uneven distribution of silica in the silage and (2) stratification and loss of silica in its passage through the intestinal tract.

LITERATURE CITED

(1) Association of Official Agricultural Chemists.
1930. official and tentative methods of analysis . . . Ed. 3, 593 pp., illus. Washington, D. C.
(2) Becker, R. B., Neal, W. M., Dawson, C. R., and Arnold, P. T. D.
1932. soybeans for silage. Fla. Agr. Expt. Sta. Bull. 255, 24 pp., illus.
(3) Bergeim, O.
1926. intestinal chemistry. IV. a method for the study of food utilization or digestibility. Jour. Biol. Chem. 70: 29–33.
(4) ———
1926. intestinal chemistry. VI. a method for the study of absorption in different parts of the gastrointestinal tract. Jour. Biol. Chem. 70: 47–50.
(5) Forbes, E. B., and Beegle, F. M., with collaboration by Fritz, C. M., Morgan, L. E., and Rhue, S. N.
1916. the mineral metabolism of the milch cow; first paper. Ohio Agr. Expt. Sta. Bull. 295, pp. 323–348.
(6) Gallup, W. D.
1928. the digestibility of the proteins of some cottonseed products. Jour. Biol. Chem. 76: 43–53.
(7) ———
1929. a note on the determination of the digestibility of protein by bergeim's method. Jour. Biol. Chem. 81: 321–324.
(8) ——— and Kuhlman, A. H.
1931. a preliminary study of the determination of the apparent digestibility of protein by modified procedures. Jour. Agr. Research 42: 665–669.
(9) Henry, W. A., and Morrison, F. B.
1923. feeds and feeding; a hand book for the student and stockman. Ed. 18, 770 pp., illus. Madison, Wis.

U. S. GOVERNMENT PRINTING OFFICE: 1936

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